Discerning Technology & Policy Implications of Global Energy Scenarios that could Stabilize Climate Change

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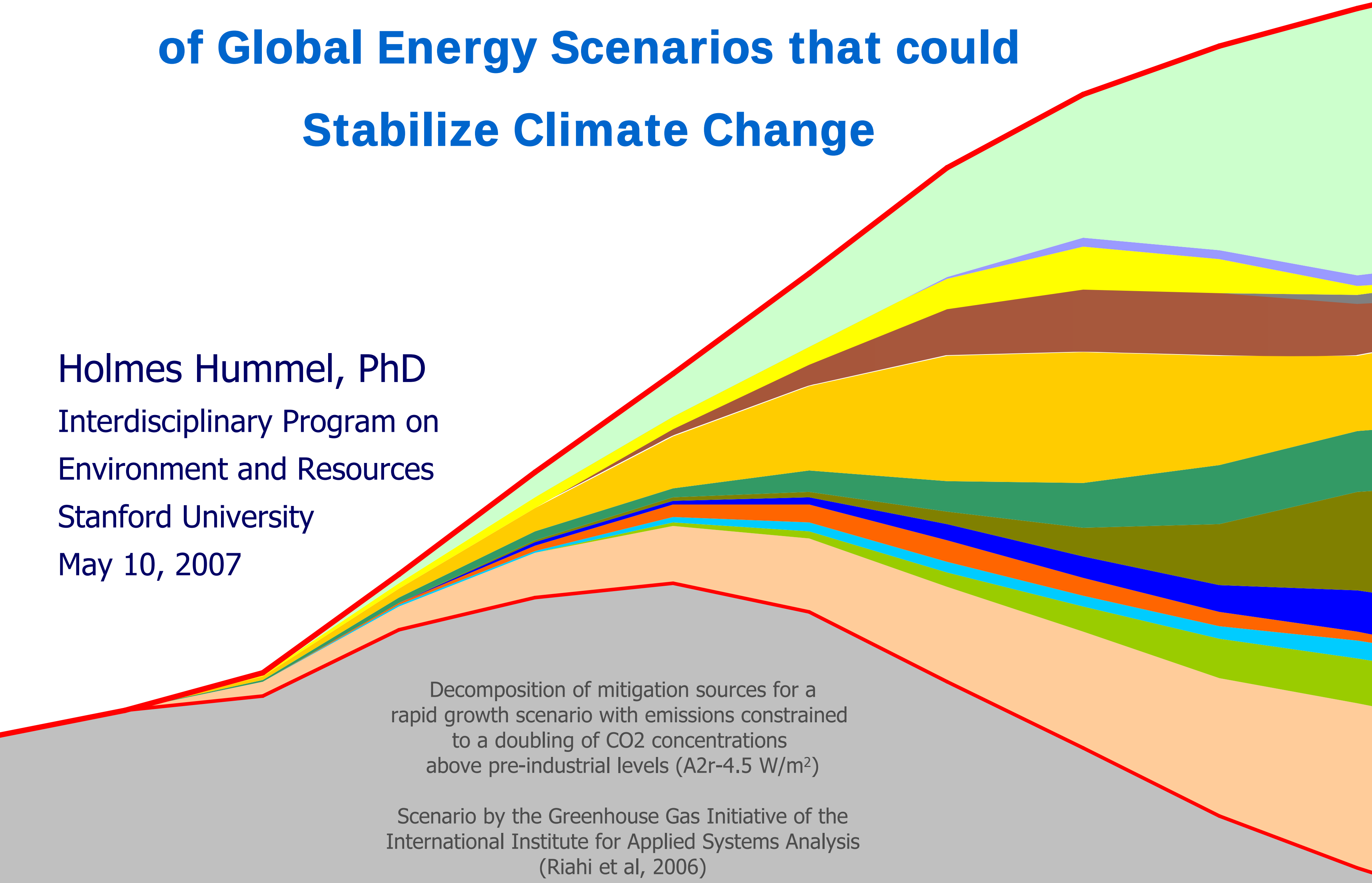
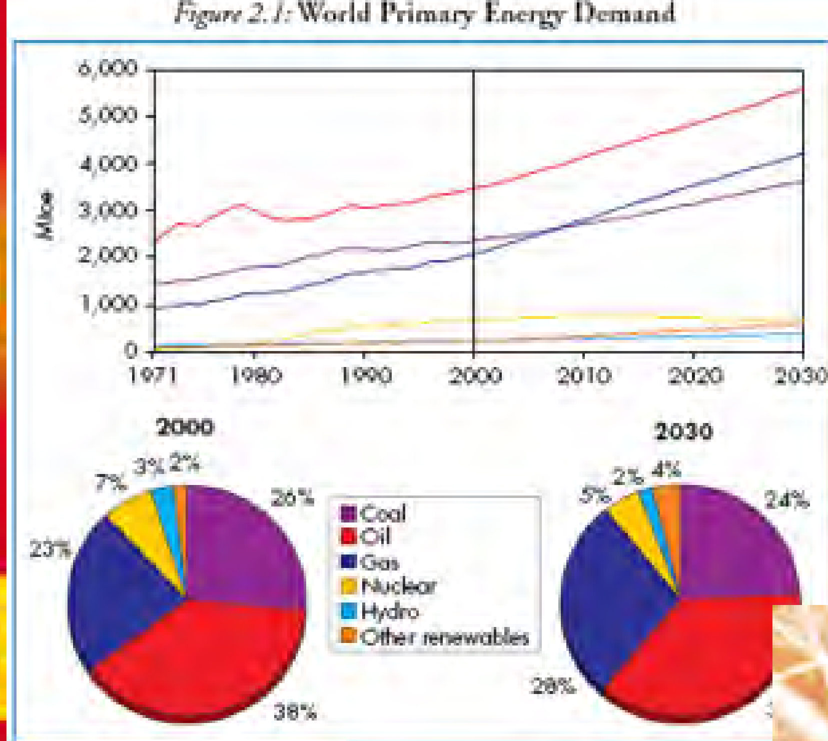
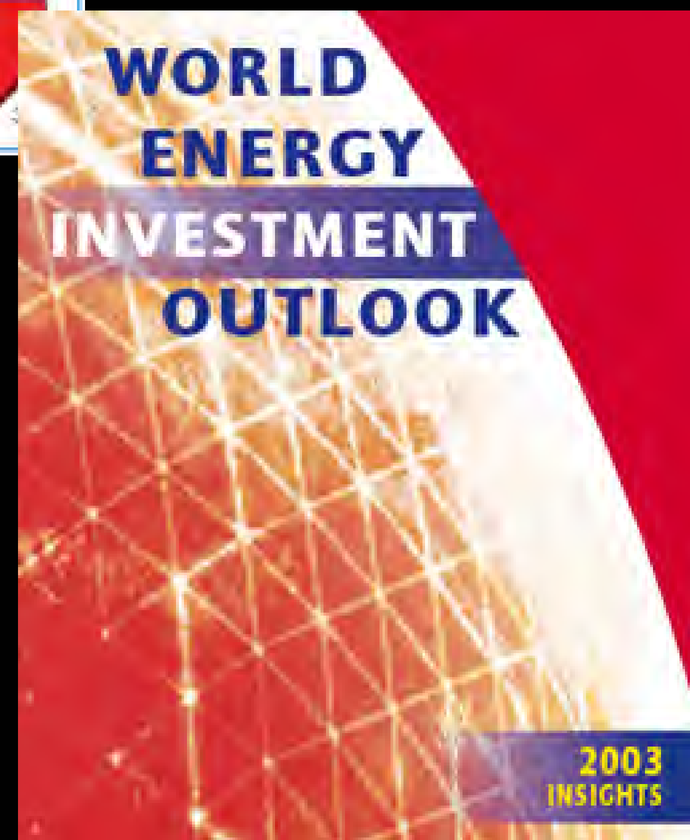
Interdisciplinary Program on Environment and Resources
Stanford University
May 10, 2007



Decomposition of mitigation sources for a rapid growth scenario with emissions constrained to a doubling of CO2 concentrations above pre-industrial levels (A2r-4.5 W/m²)

Scenario by the Greenhouse Gas Initiative of the International Institute for Applied Systems Analysis (Riahi et al, 2006)





According to the IEA in 2003,
investment needed thru 2030 is $16 trillion…

At least $10 trillion for fossil fuels
and their delivery infrastructure…

Scenarios of many types powerfully shape perceptions about the future that frame near term decisions.

"2 billion people will still be without electricity…"

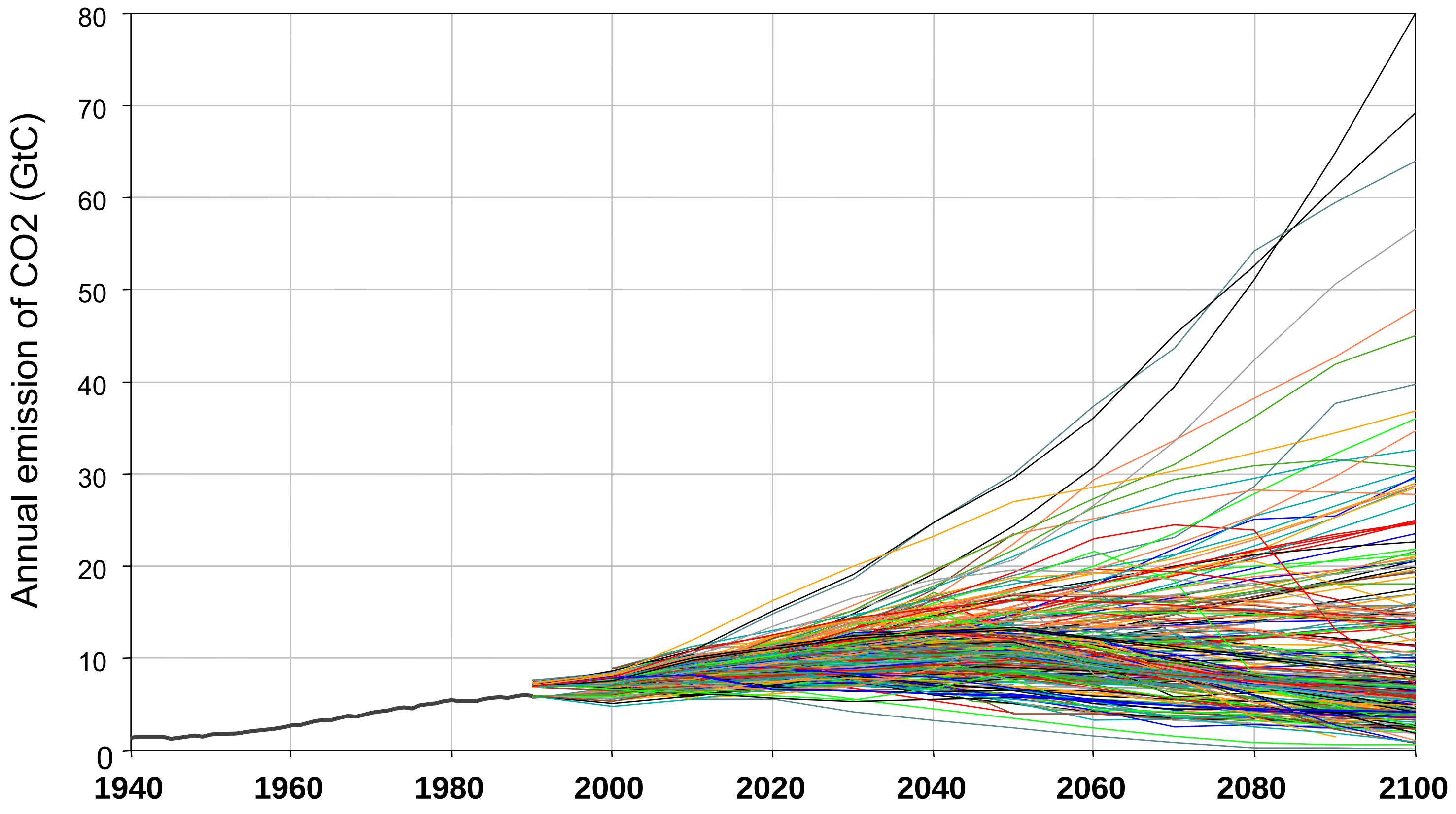
"We need to double the nuclear power capacity…"

"We need technologies that don't exist yet…"

"Stabilizing climate change requires…"


INTERNATIONAL ENERGY AGENCY
ENERGY TECHNOLOGY PERSPECTIVES
WBGU
German Advisory Council on Global Change (WBGU)
Special Report on Emissions Scenarios
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
Climate Change 2007: The Physical Science Basis
Summary for Policymakers
Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change
PEW CENTER
Global CLIMATE CHANGE

Scenarios for Global Carbon Dioxide Emissions



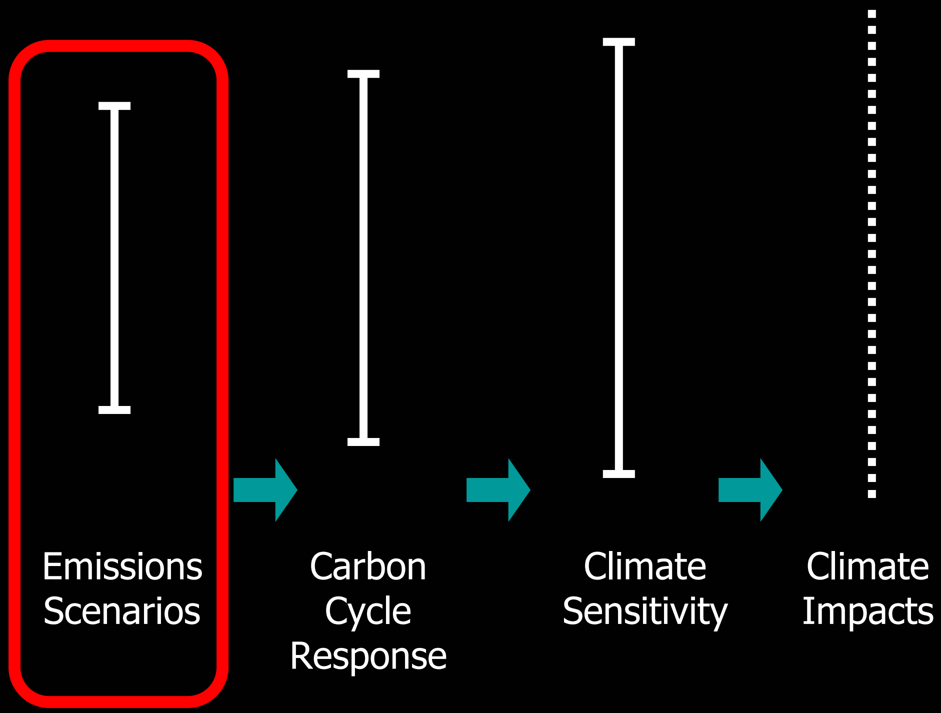
Data: National Institute for Environmental Studies, Japan; Graph: International Institute for Applied Systems Analysis

What do they mean?

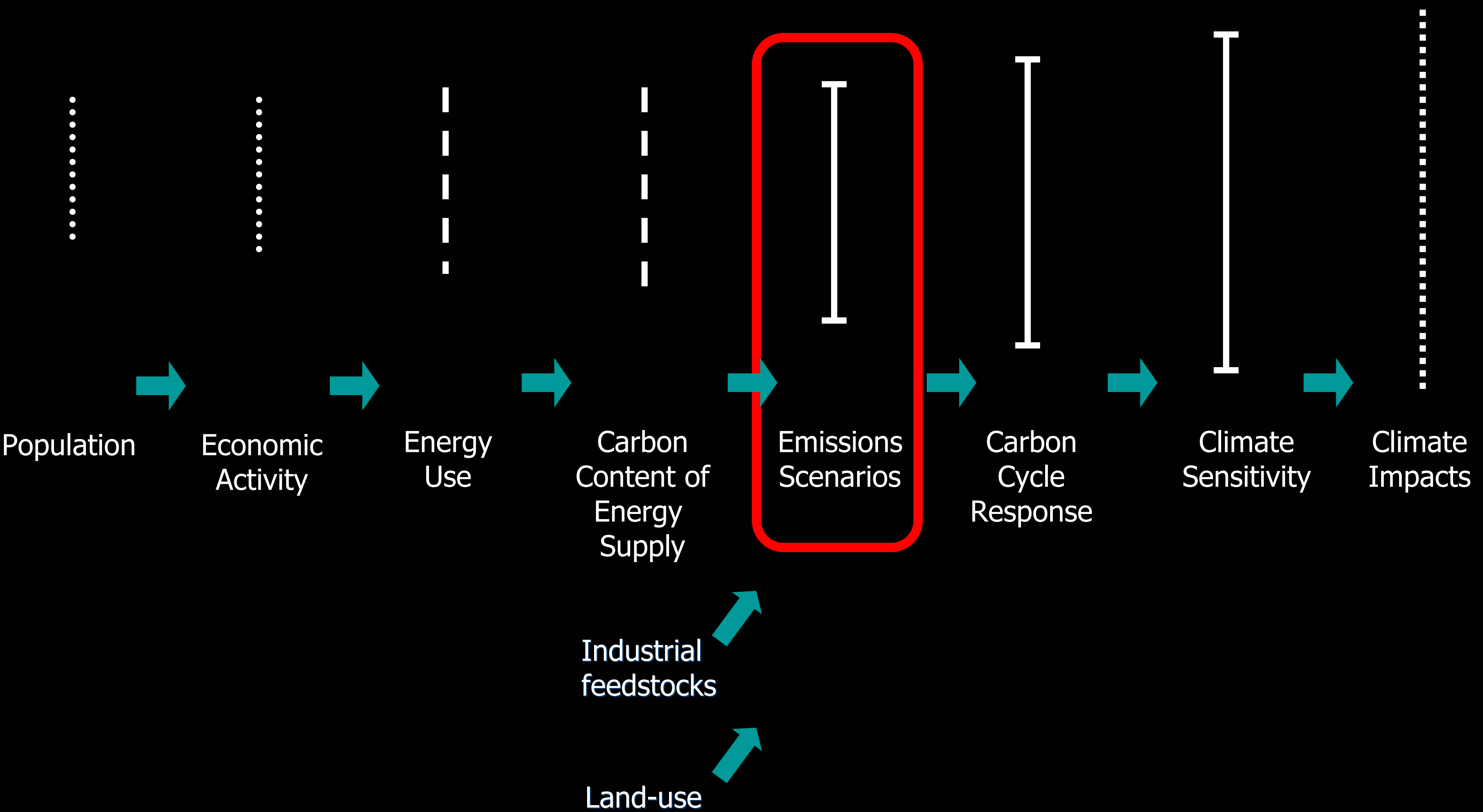
How do I know?

Does it make sense?

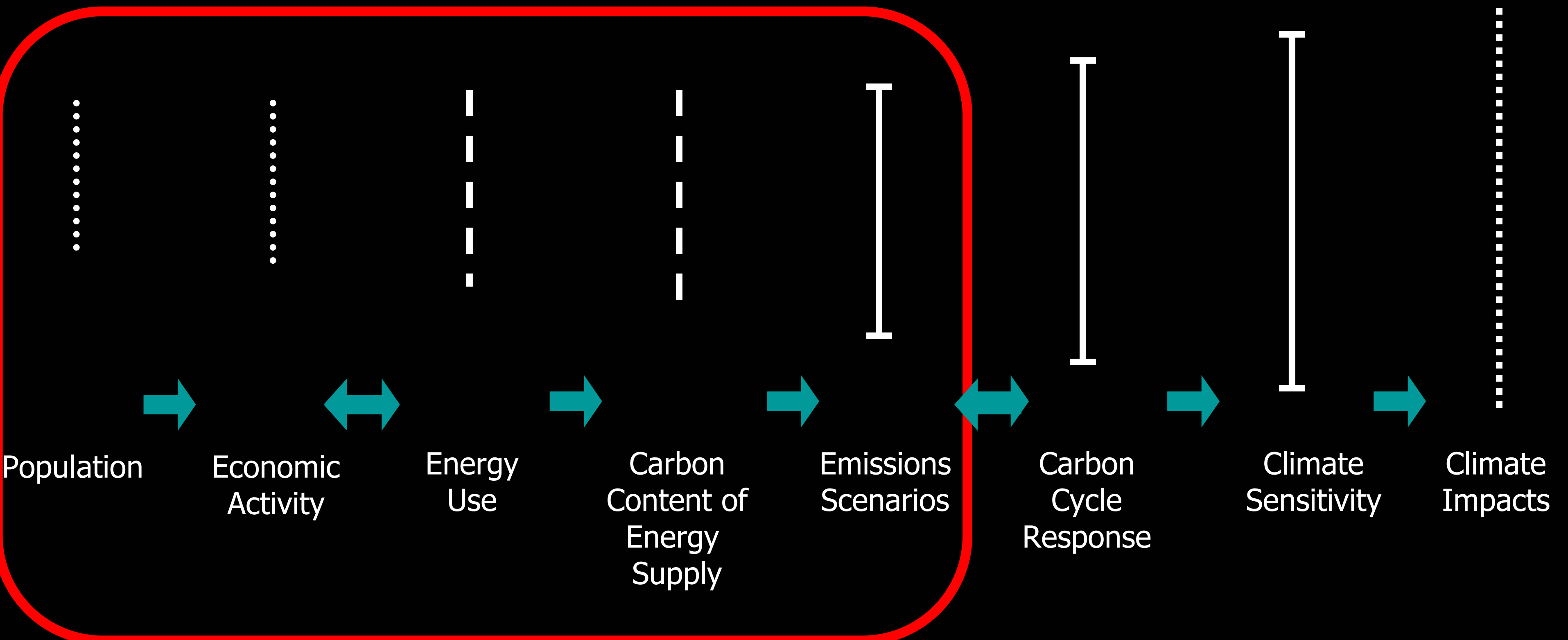
Simplified Line of Scenario Logic: Energy to Emissions



Simplified Line of Scenario Logic: Energy to Emissions



Simplified Line of Scenario Logic: Energy to Emissions

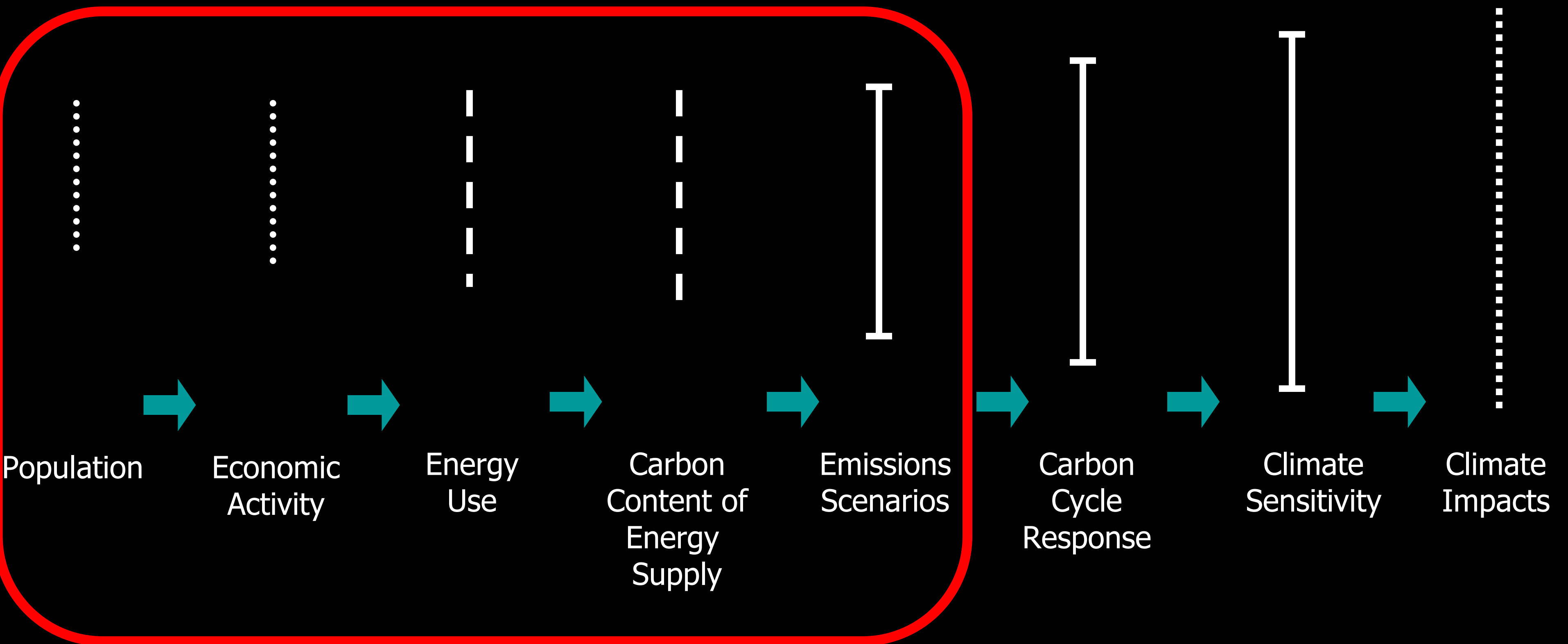


Deep uncertainty:

Parameter values + Relationship between the parameters

Scenario analysis is an *appropriate* technique for exploring deep uncertainty.

Simplified Line of Scenario Logic: Energy to Emissions



Energy and emissions scenario analysis aims to explore deep uncertainty to support risk management decisions.

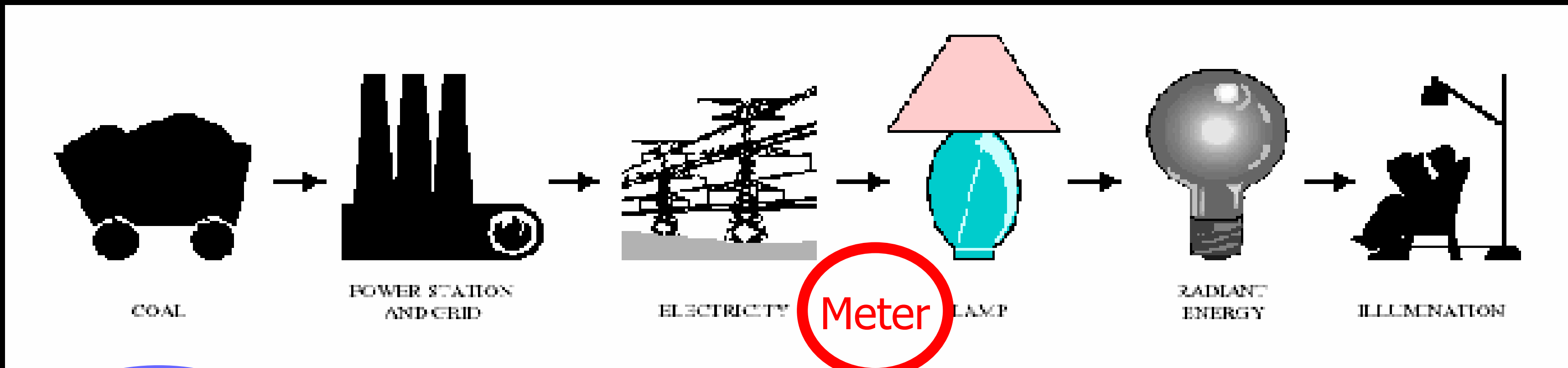
Exploring Energy Futures

model agnostic

- Constructing a common framework for interpretation
  - How do policy interventions affect key drivers of emissions?
  - What are the sources of mitigation in stabilization scenarios?
  - Accounting for direct equivalent energy accounting
- Insights from analyzing several widely-cited energy scenarios
- What is the role of energy efficiency?
- Summary of findings, and your questions

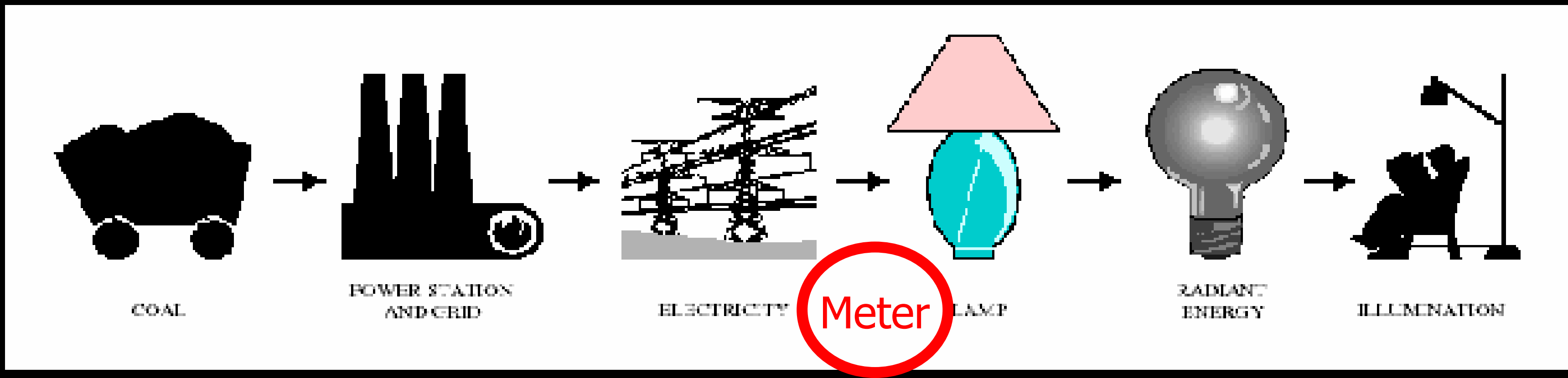
$$\overbrace{\cancel{P}}^{\text{People}} \cdot \overbrace{\frac{\cancel{GDP}}{\cancel{P}}}^{\text{Average Income}} \cdot \overbrace{\frac{\cancel{E}}{\cancel{GDP}}}^{\text{Energy Intensity of Economy}} \cdot \overbrace{\frac{C}{\cancel{E}}}^{\text{Carbon Intensity of Energy}} = \overbrace{C}^{\text{Carbon Emissions}}$$

"Kaya Identity" *(Kaya, 1991)*



Primary Energy | Final Energy | End Use | Energy Service

$$\overbrace{P}^{\text{People}} \cdot \overbrace{\frac{GDP}{P}}^{\text{Average Income}} \cdot \overbrace{\frac{E}{GDP}}^{\text{Energy Intensity of Economy}} \cdot \overbrace{\frac{C}{E}}^{\text{Carbon Intensity of Energy}} = \overbrace{C}^{\text{Carbon Emissions}}$$



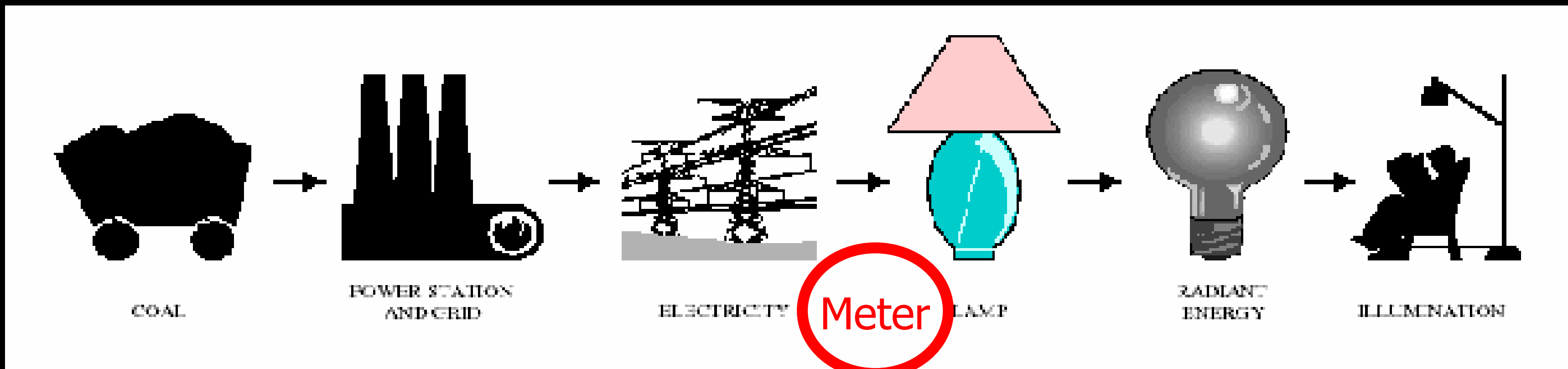
Primary Energy

Final Energy

End Use

Energy Service

$$\overbrace{P}^{\text{People}} \cdot \overbrace{\frac{GDP}{P}}^{\text{Average Income}} \cdot \overbrace{\frac{}{GDP}}^{\text{Energy Intensity of Economy}} \cdot \frac{PE}{} \cdot \overbrace{\frac{C}{PE}}^{\text{Carbon Intensity of Energy}} = \overbrace{C}^{\text{Carbon Emissions}}$$



Primary Energy

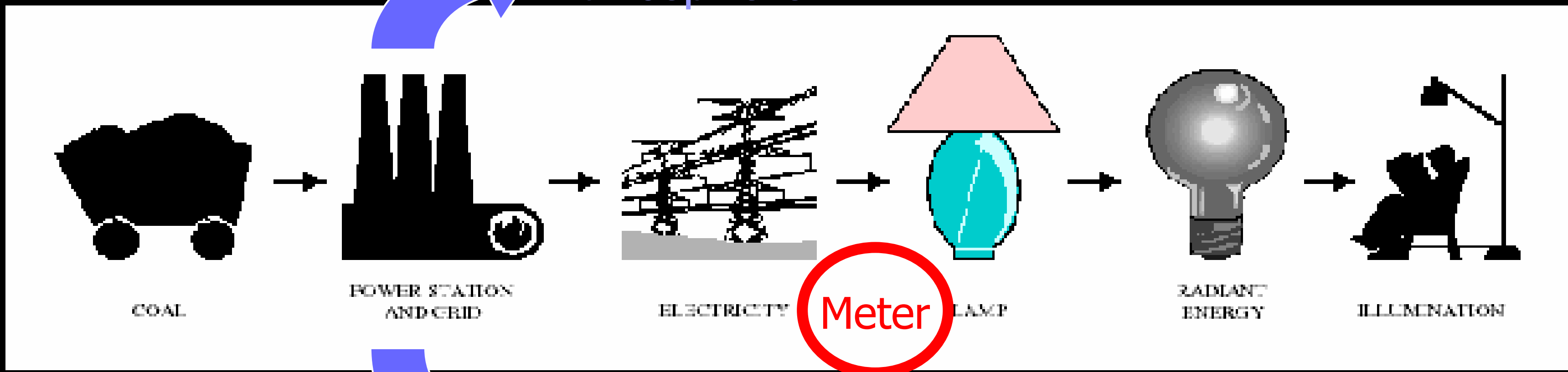
Final Energy

End Use

Energy Service

$$\overbrace{P}^{\text{People}} \cdot \overbrace{\frac{GDP}{P}}^{\text{Average Income}} \cdot \overbrace{\frac{FE}{GDP}}^{\text{Energy Intensity of Economy}} \cdot \overbrace{\frac{PE}{FE}}^{\text{Energy Supply Loss Factor}} \cdot \overbrace{\frac{C}{PE}}^{\text{Carbon Intensity of Energy}} = \overbrace{C}^{\text{Carbon Emissions}}$$

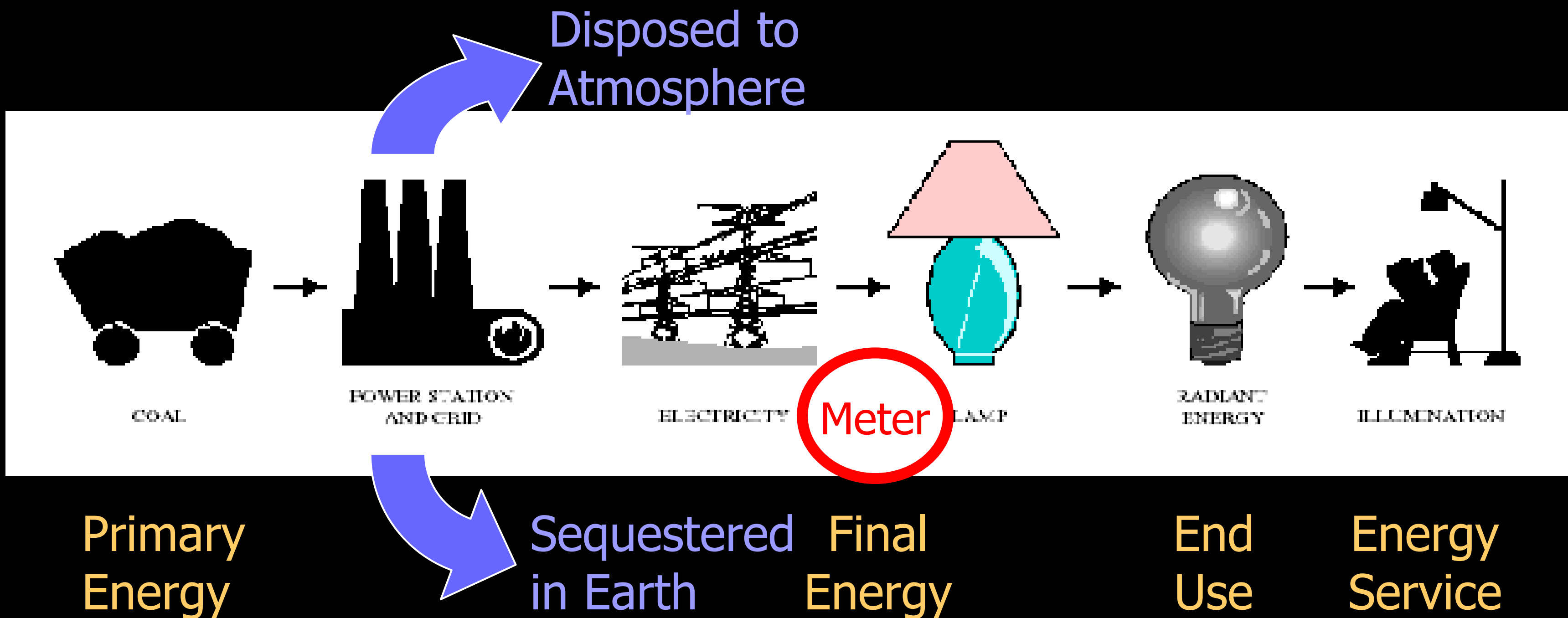
Disposed to Atmosphere



Sequestered in Earth

Primary Energy | Final Energy | End Use | Energy Service

$$\overbrace{P}^{\text{People}} \cdot \overbrace{\frac{GDP}{P}}^{\text{Average Income}} \cdot \overbrace{\frac{FE}{GDP}}^{\text{Energy Intensity of Economy}} \cdot \overbrace{\frac{PE}{FE}}^{\text{Energy Supply Loss Factor}} \cdot \overbrace{\frac{C}{PE}}^{\text{Carbon Intensity of Energy}} = \overbrace{C}^{\text{Carbon Emissions}}$$



$$\overbrace{P}^{\text{People}} \cdot \overbrace{\frac{GDP}{P}}^{\text{Average Income}} \cdot \overbrace{\frac{FE}{GDP}}^{\text{Energy Intensity of Economy}} \cdot \overbrace{\frac{PE}{FE}}^{\text{Energy Supply Loss Factor}} \cdot \overbrace{\frac{TC}{PE}}^{\text{Carbon Intensity of Energy}} \cdot \overbrace{\frac{C}{TC}}^{\text{Fraction Disposed to Atmosphere}} = \overbrace{C}^{\text{Carbon Emissions}}$$

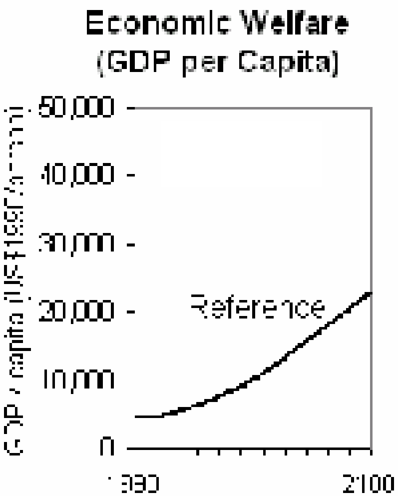
Decomposing Key Drivers in a Sample Scenario

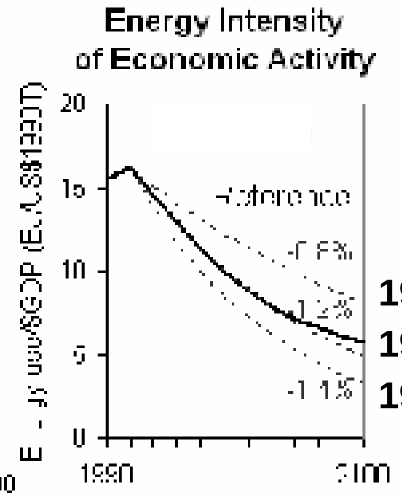
Reference: “Dynamics as Usual” (B2) | Stabilization target: 550ppm CO2 | Model: MiniCAM

First, using the familiar Kaya Identity…

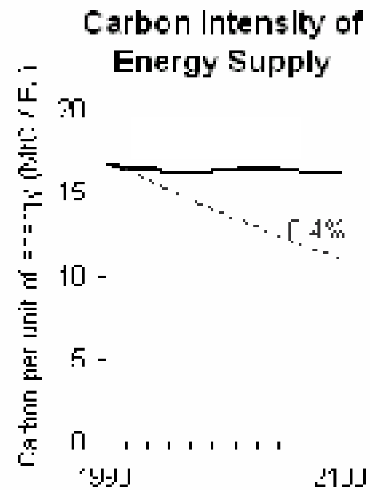
$$\frac{GDP}{P} \qquad \frac{PE}{GDP} \qquad \frac{C}{PE}$$

Reference: "Dynamics as Usual" (B2) Stabilization target: 550ppm CO2 Model: MiniCAM





1971-1980: -0.8%
1980-2000: -1.2%
1995-2000: -1.6%

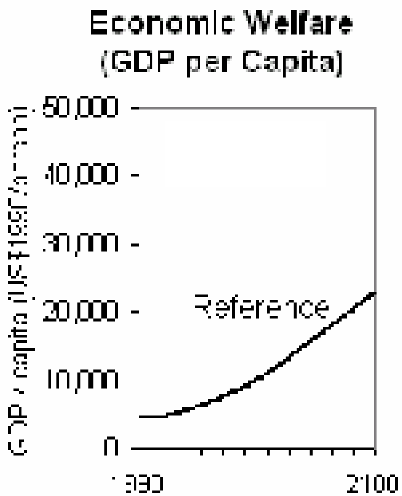


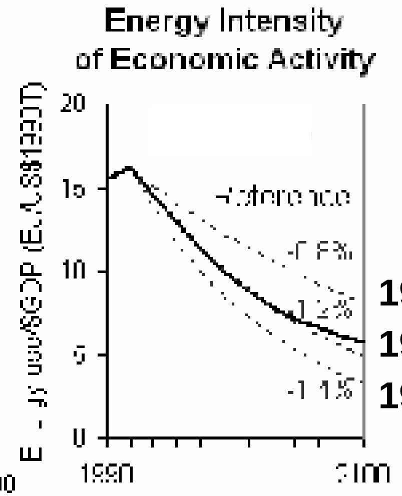
Annual Rate of Decarbonization: 0.4%

1920-2000

$$\frac{GDP}{P} \qquad \frac{PE}{GDP} \qquad \frac{C}{PE}$$

Reference: "Dynamics as Usual" (B2) Stabilization target: 550ppm CO2 Model: MiniCAM





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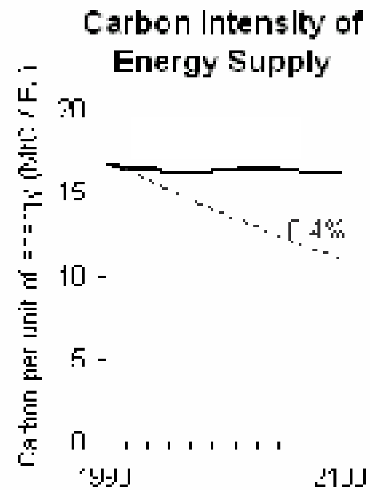

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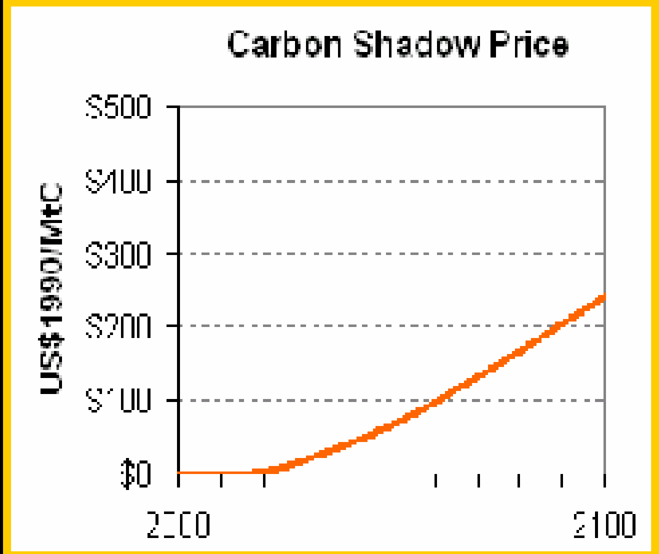

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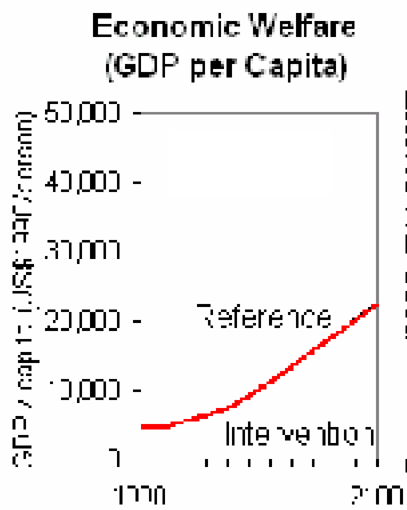

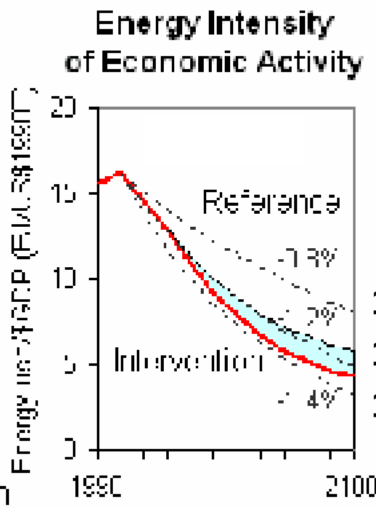

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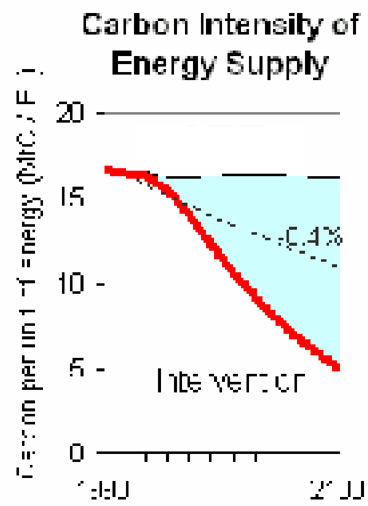
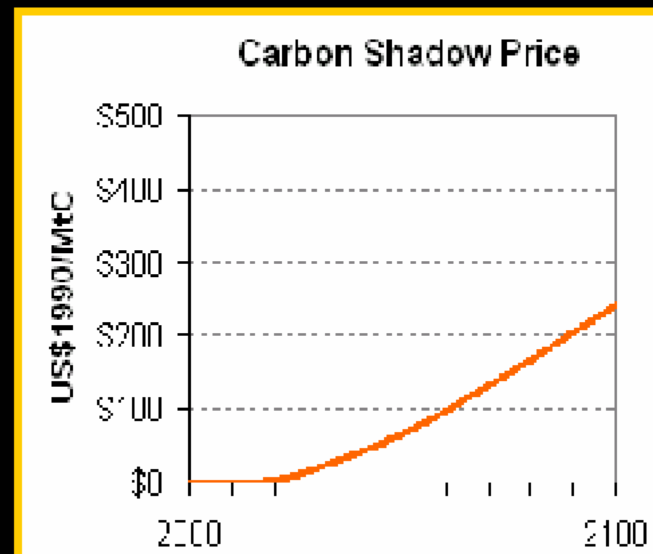


GDP / P **PE / GDP** **C / PE**



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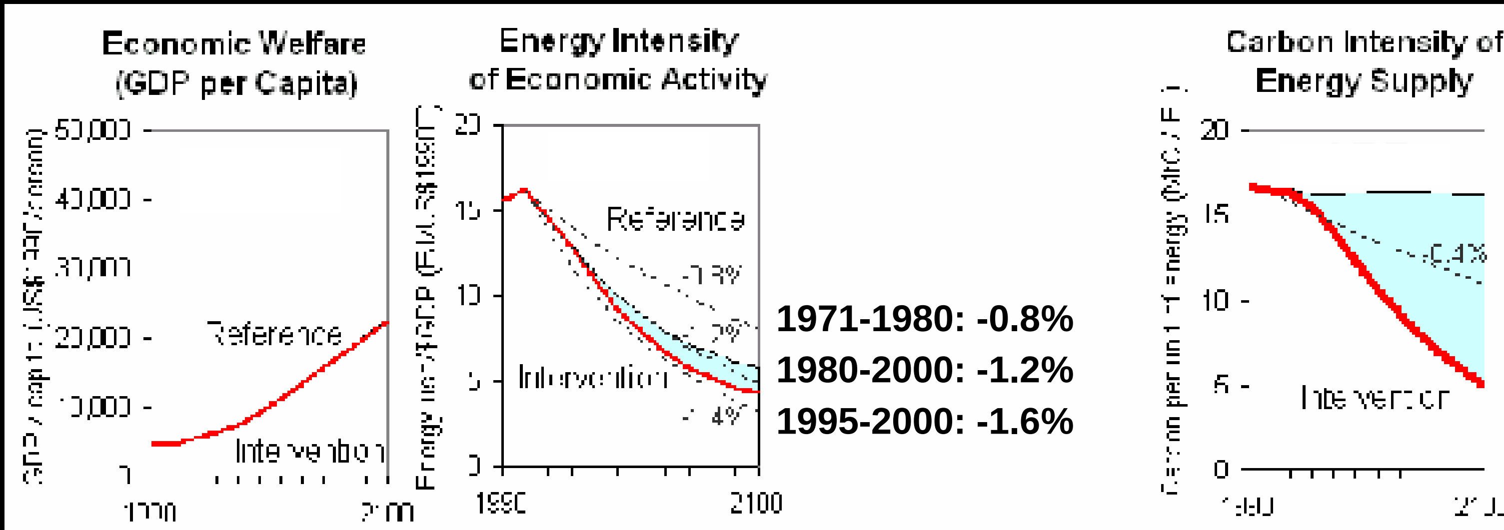
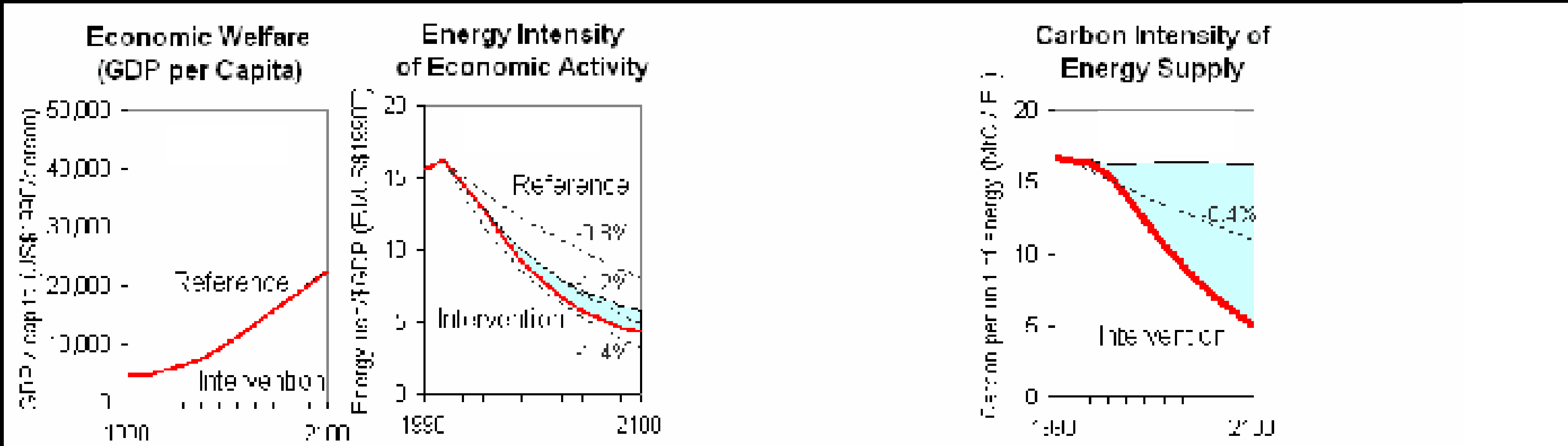


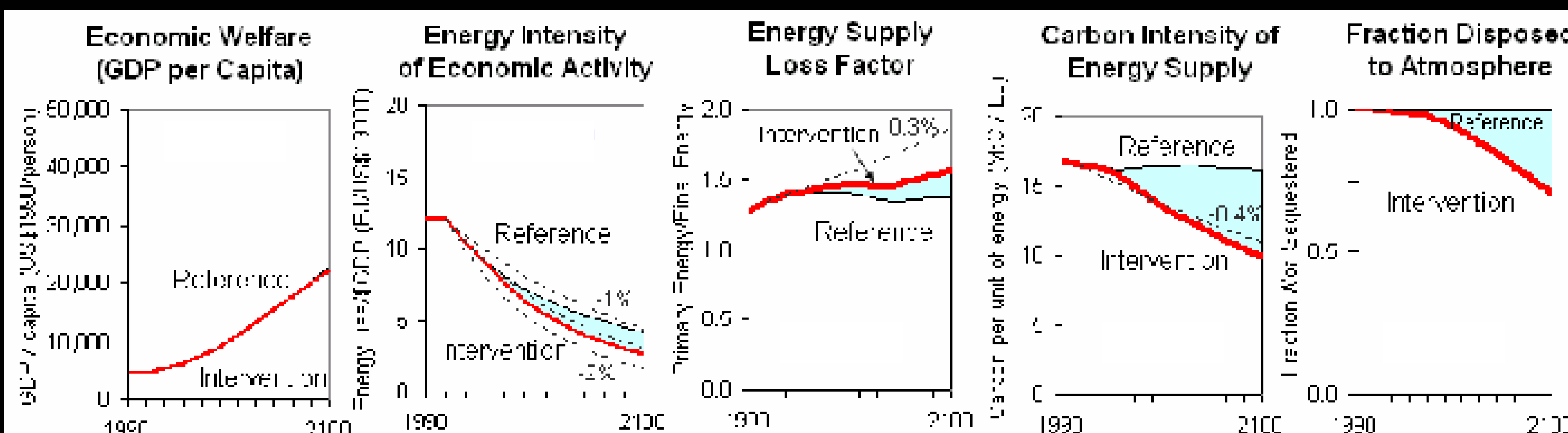
$\frac{GDP}{P}$ $\frac{PE}{GDP}$ $\frac{C}{PE}$

Next, using the expanded decomposition…

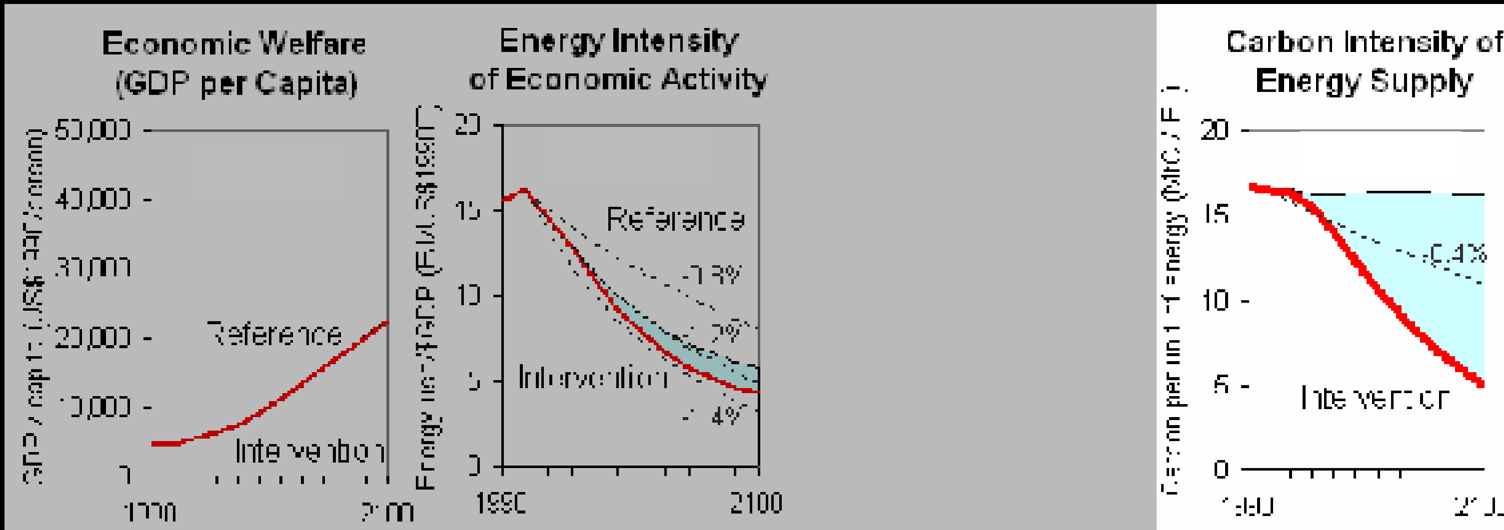
Reference: "Dynamics as Usual" (B2) Stabilization target: 550ppm CO2 Model: MiniCAM



$$\frac{GDP}{P} \qquad \frac{PE}{GDP} \qquad \frac{C}{PE}$$



$$\frac{GDP}{P} \bullet \frac{FE}{GDP} \bullet \frac{PE}{FE} \bullet \frac{TC}{PE} \bullet \frac{C}{TC}$$

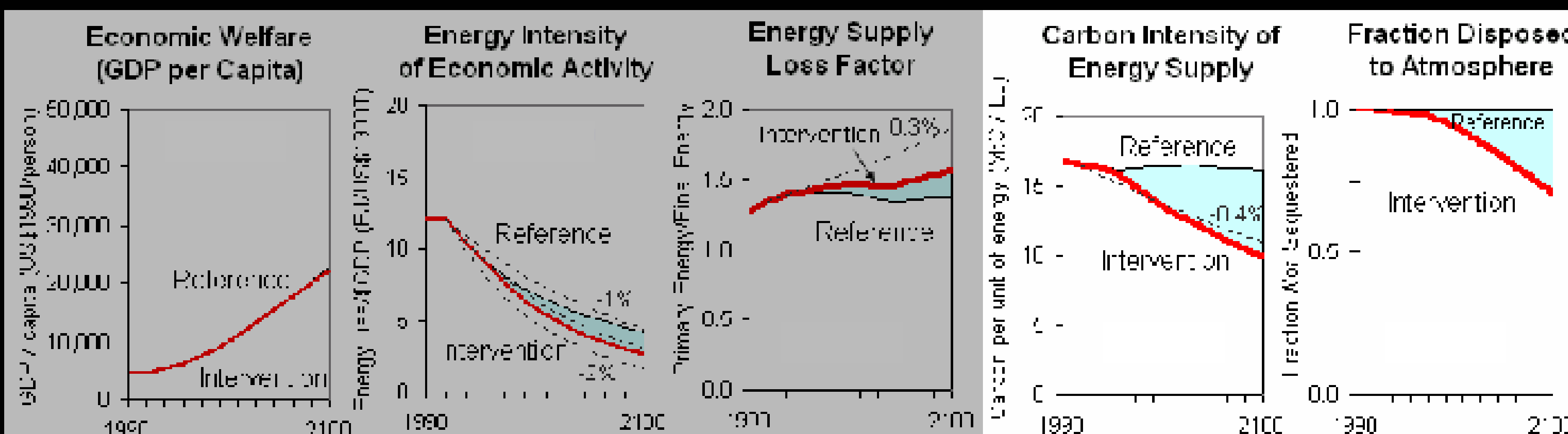


1920-1994

1980-2000

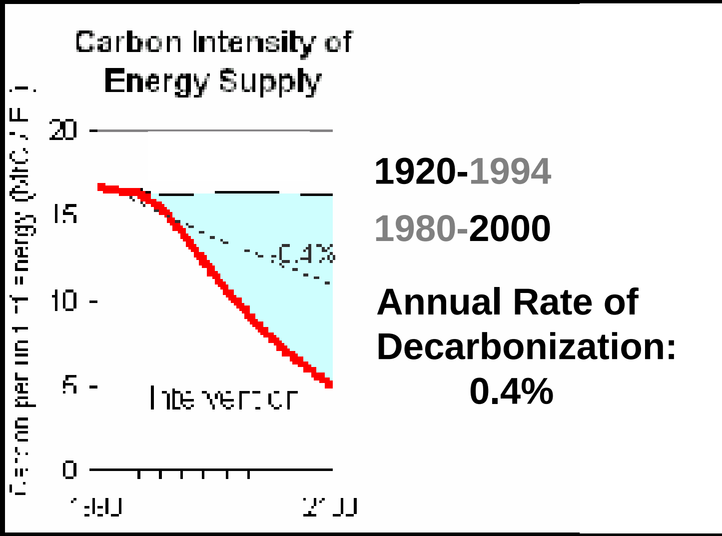
Annual Rate of Decarbonization: 0.4%

$$\frac{GDP}{P} \qquad \frac{PE}{GDP} \qquad \frac{C}{PE}$$

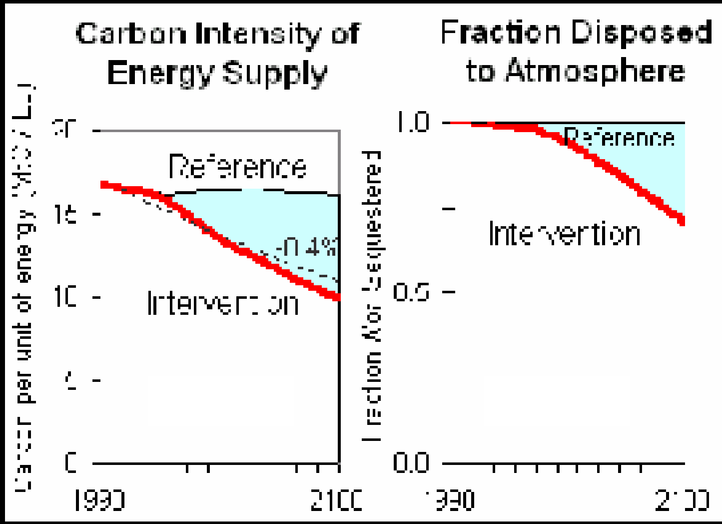


$$\frac{GDP}{P} \bullet \frac{FE}{GDP} \bullet \frac{PE}{FE} \bullet \frac{TC}{PE} \bullet \frac{C}{TC}$$

Holding carbon intensity constant at 1990 levels in the reference case diverges from ‘dynamics as usual’.



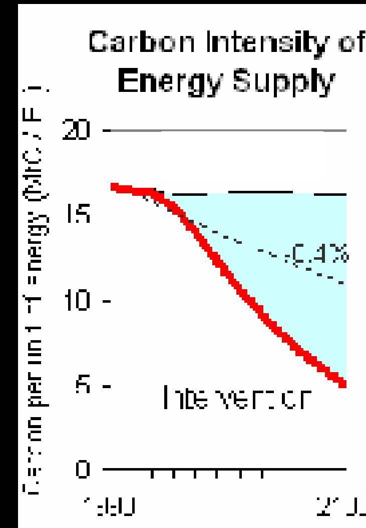
$$\frac{C}{PE}$$



- $\frac{TC}{PE}$
- $\frac{C}{TC}$

Holding carbon intensity constant at 1990 levels in the reference case diverges from 'dynamics as usual'.

Fuel switching implied to be a response to the policy intervention may have occurred anyway if decarbonization rate over the last 80 years had persisted.

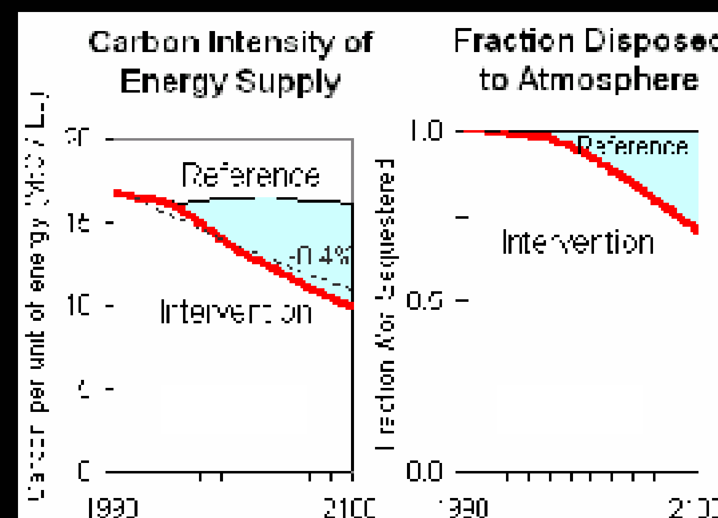


1920-1994

1980-2000

Annual Rate of Decarbonization: 0.4%

$\frac{C}{PE}$

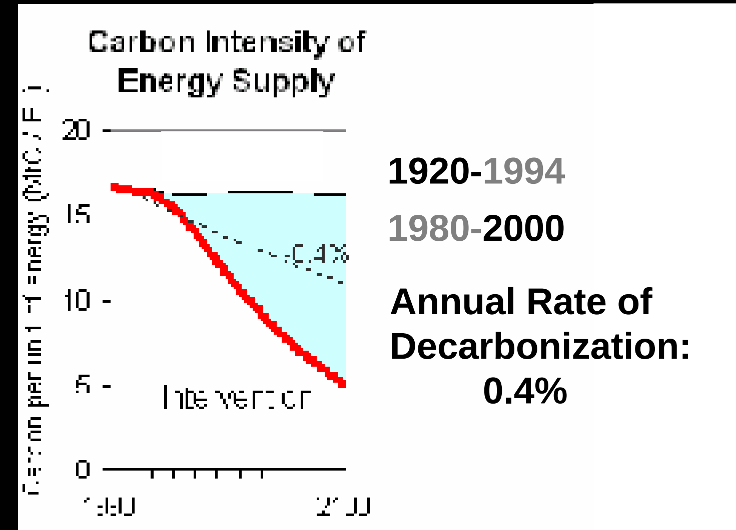


- $\frac{TC}{PE}$
- $\frac{C}{TC}$

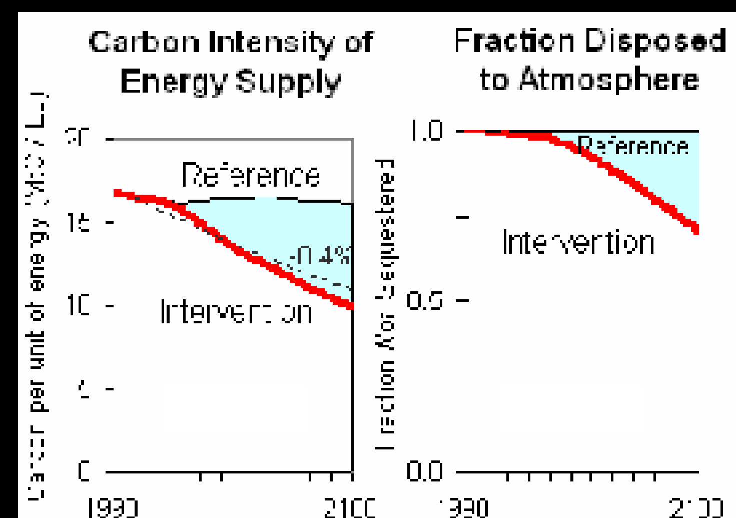
Holding carbon intensity constant at 1990 levels in the reference case diverges from 'dynamics as usual'.

Fuel switching implied to be a response to the policy intervention may have occurred anyway if decarbonization rate over the last 80 years had persisted.

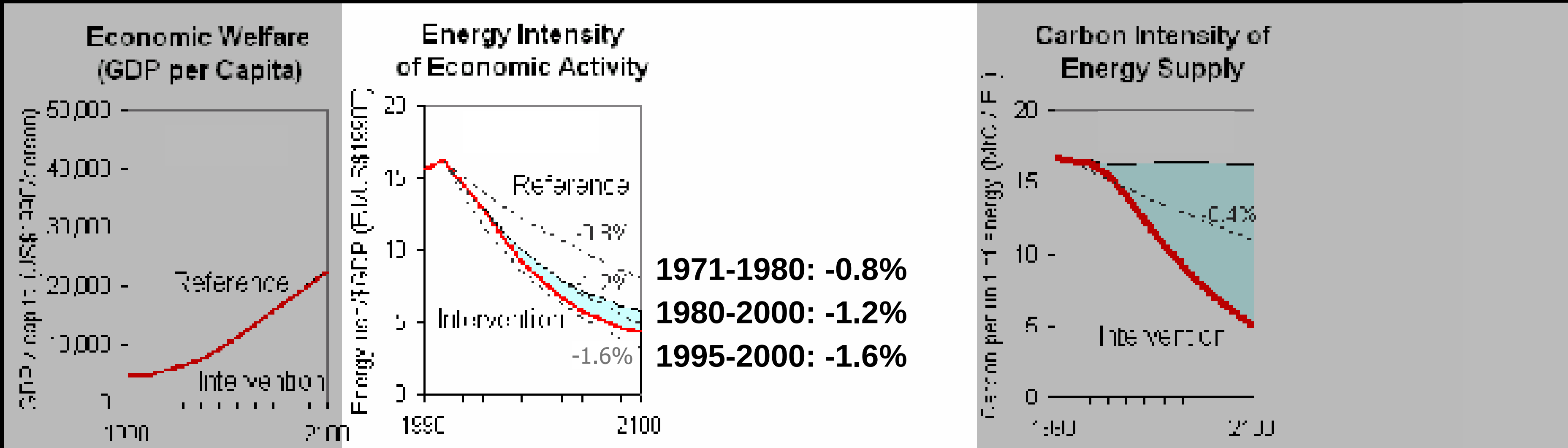
The rest of the mitigation – which may have been interpreted as accelerated decarbonization of the energy supply – is actually from carbon sequestration.



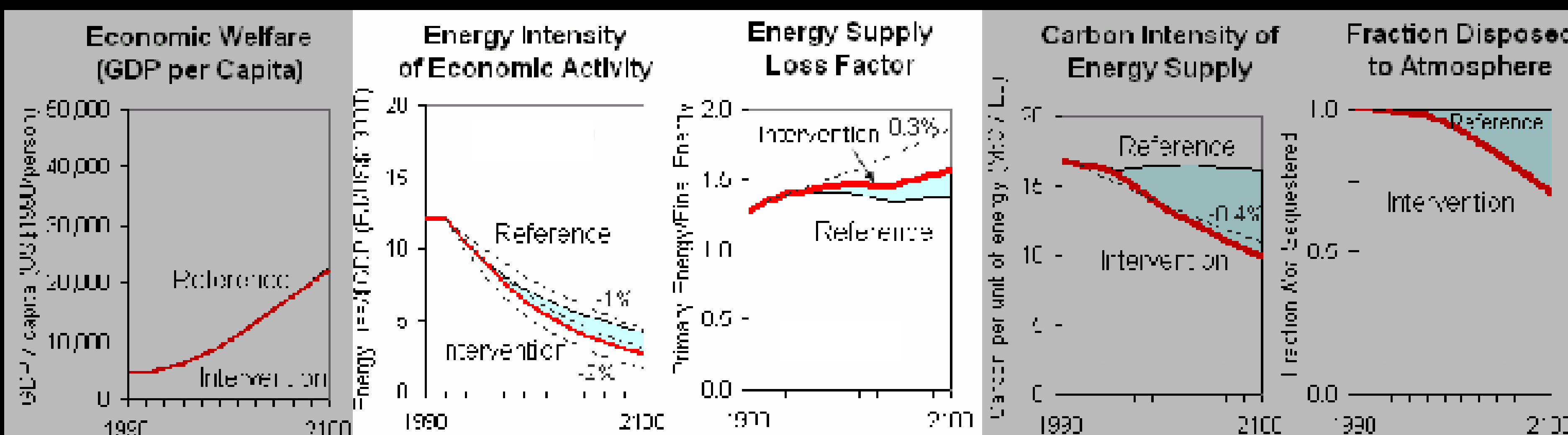
$\frac{C}{PE}$



- $\frac{TC}{PE}$
- $\frac{C}{TC}$

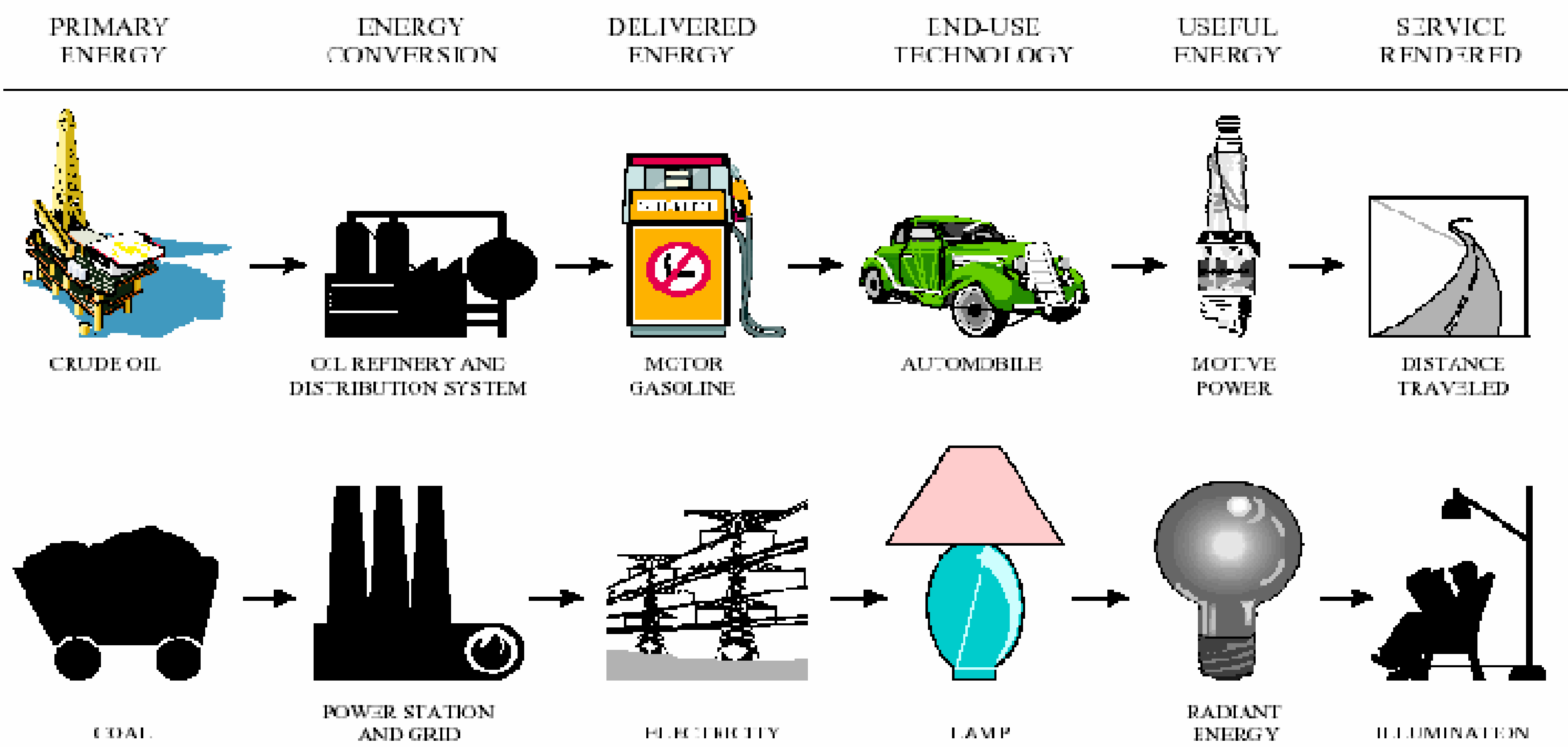


$$\frac{GDP}{P} \qquad \frac{PE}{GDP} \qquad \frac{C}{PE}$$



$$\frac{GDP}{P} \bullet \frac{FE}{GDP} \bullet \frac{PE}{FE} \bullet \frac{TC}{PE} \bullet \frac{C}{TC}$$

Primary Energy — Final Energy — Productive Use

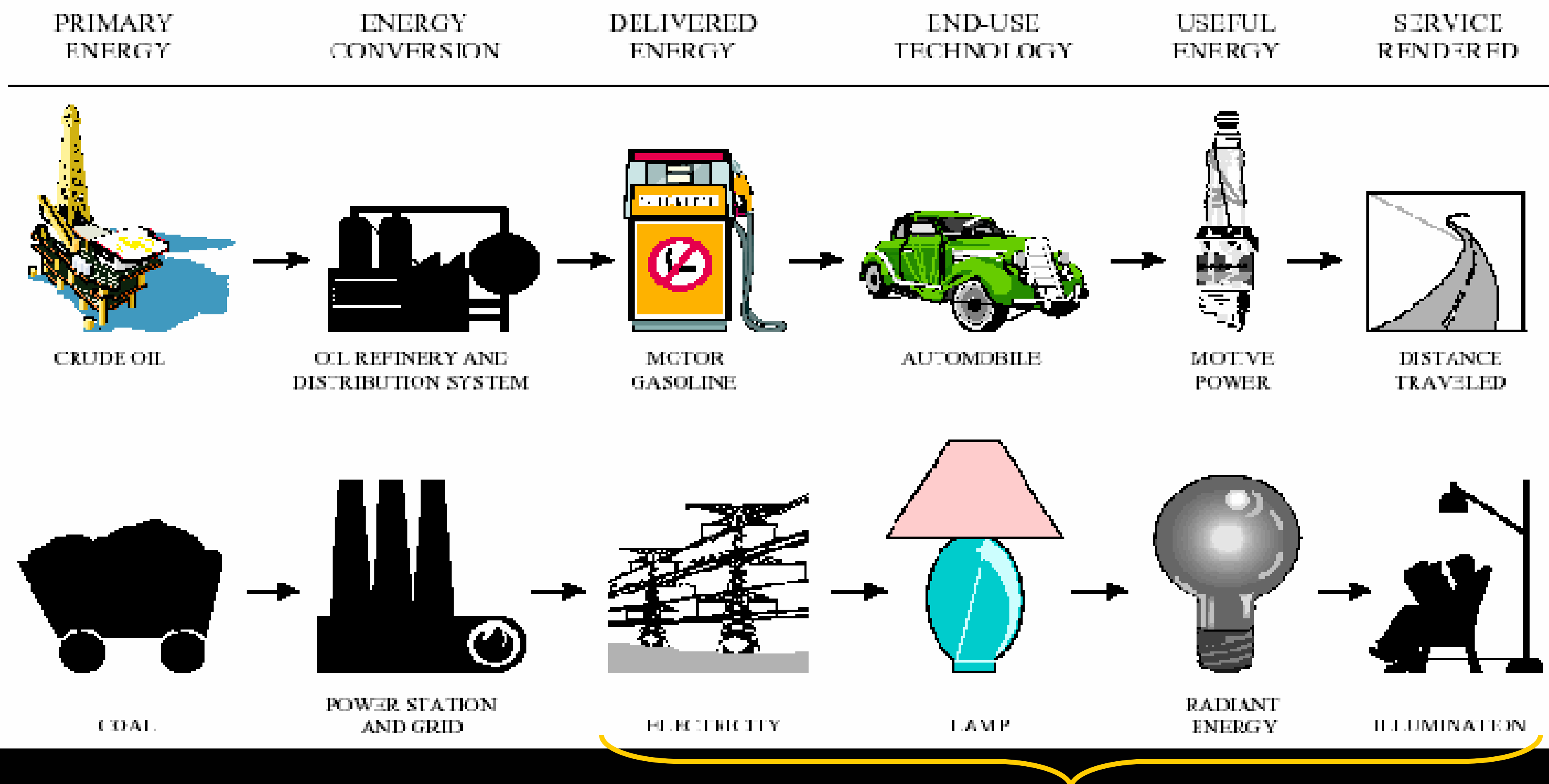


- **Efficiency:** More energy delivered per energy input
- **Fuel Switching:** Moving from coal to natural gas
- **Electrification:** Changing the share of electricity in FE

Primary Energy

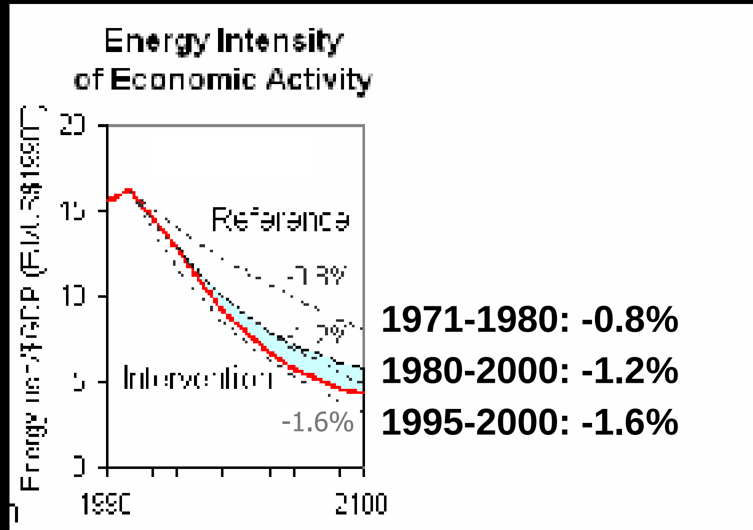
Final Energy

Productive Use

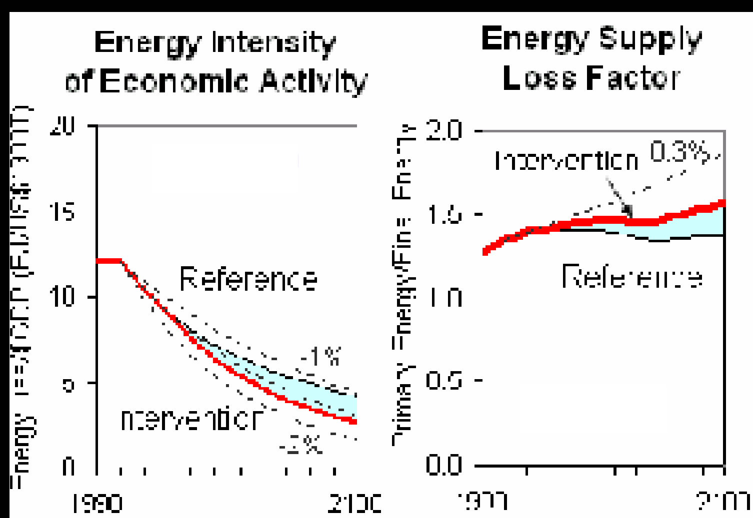


- **Conservation:** Less non-productive energy use
- **Energy Intensity:** More productivity per energy input
- **Structural Change:** Same productivity, less energy use (Shift toward service economy)

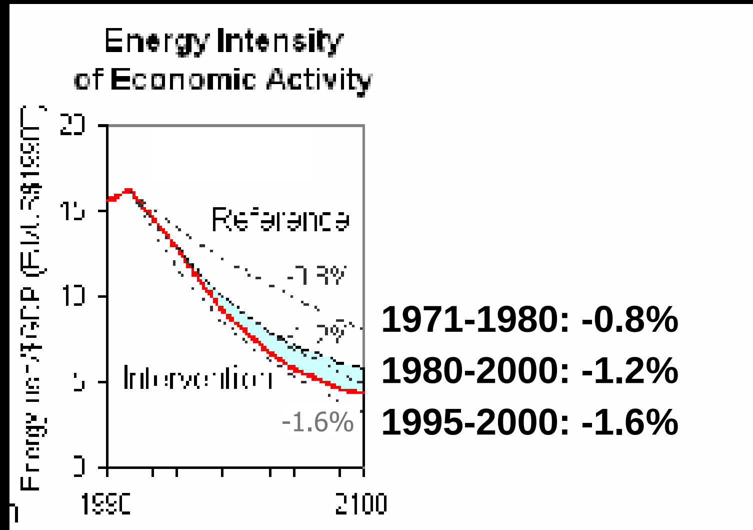
The reference case extends the 1980-2000 trend, and the policy intervention accelerates that improvement nearly to 1995-2000 levels.



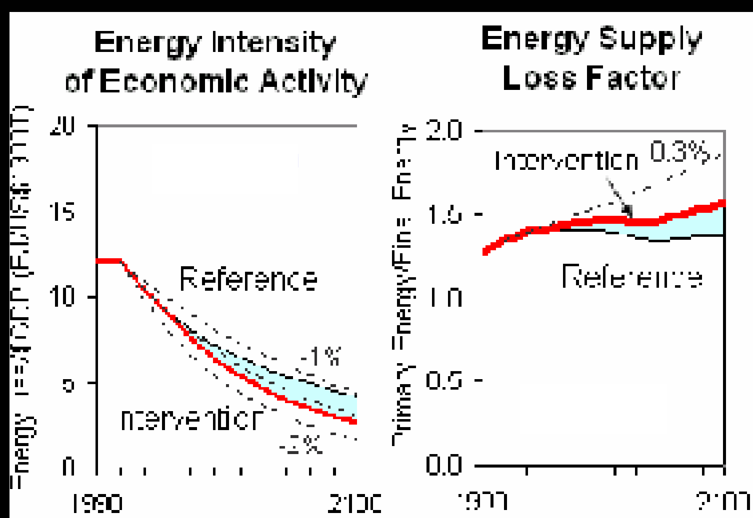
$$\frac{PE}{GDP}$$



- $\frac{FE}{GDP}$
- $\frac{PE}{FE}$

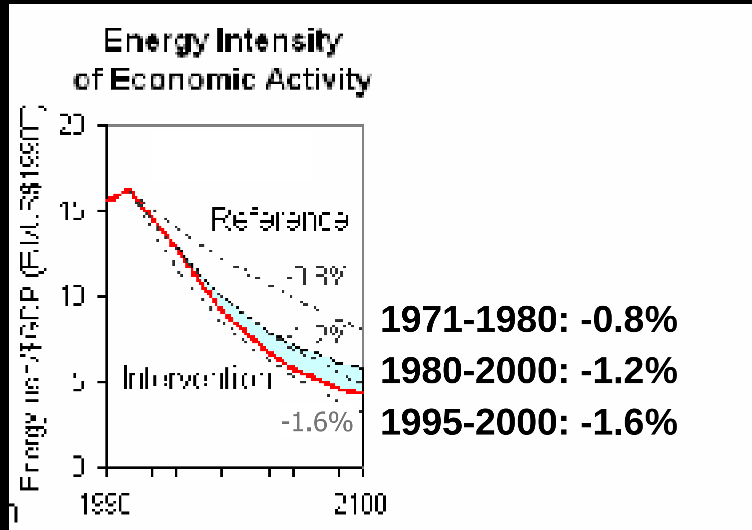


$$\frac{PE}{GDP}$$

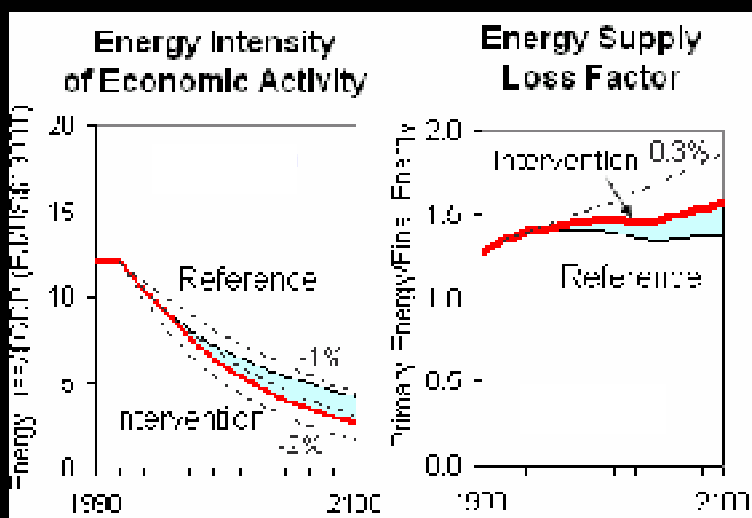


Once decomposed, we see a very optimistic reference case assumption about efficiency in energy supply.

- $\frac{FE}{GDP}$
- $\frac{PE}{FE}$



$$\frac{PE}{GDP}$$



- $\frac{FE}{GDP}$
- $\frac{PE}{FE}$

Once decomposed, we see a very optimistic reference case assumptio about efficiency in energy supply.

FE/GDP sags, and the rising carbon price brings the rate of improvemen to a level only slightly higher than the 1980-2000 trend.

Exploring Energy Futures

model agnostic

- Constructing a common framework for interpretation
  - How do policy interventions affect key drivers of emissions?
  - What are the sources of mitigation in stabilization scenarios?
  - Accounting for direct equivalent energy accounting
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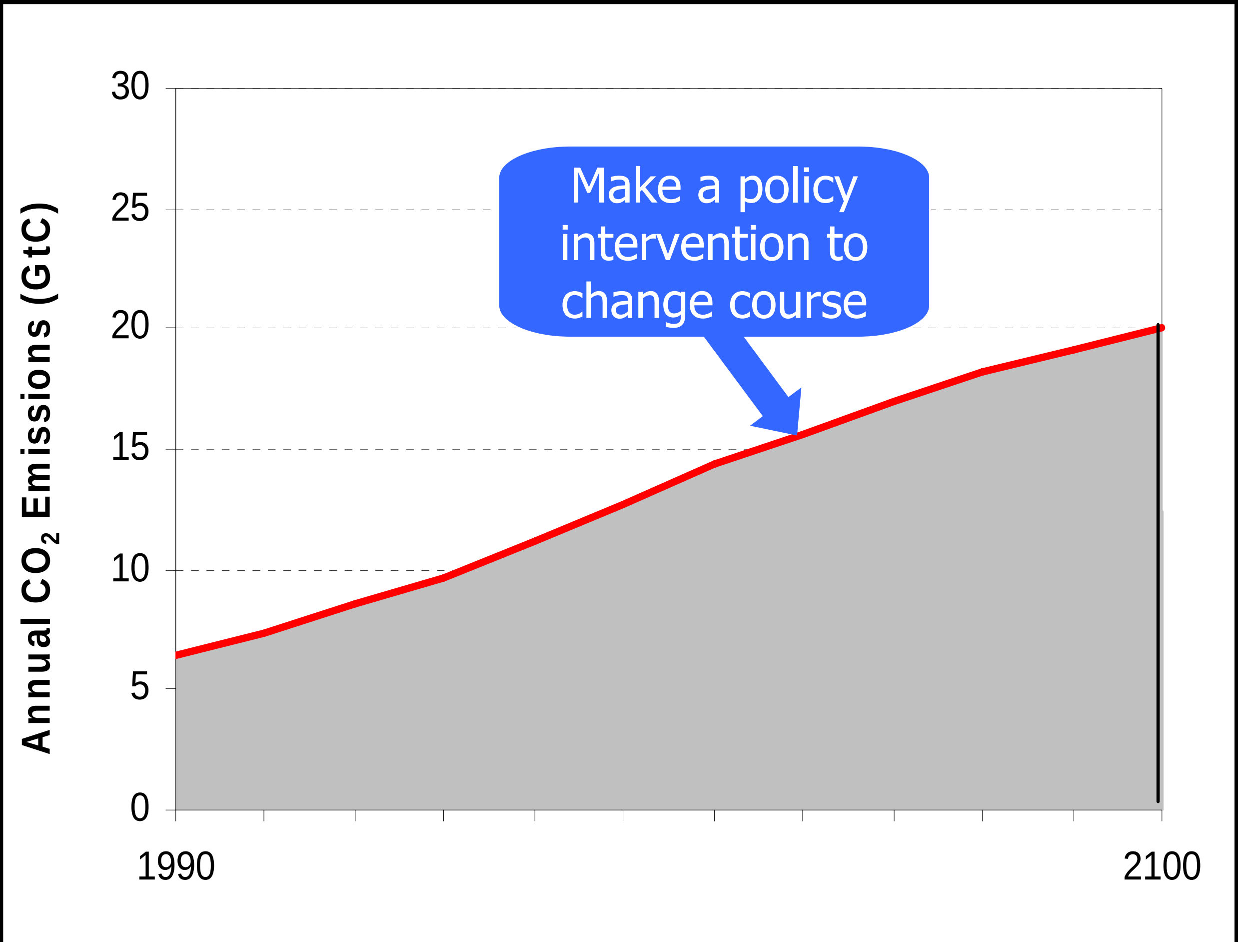
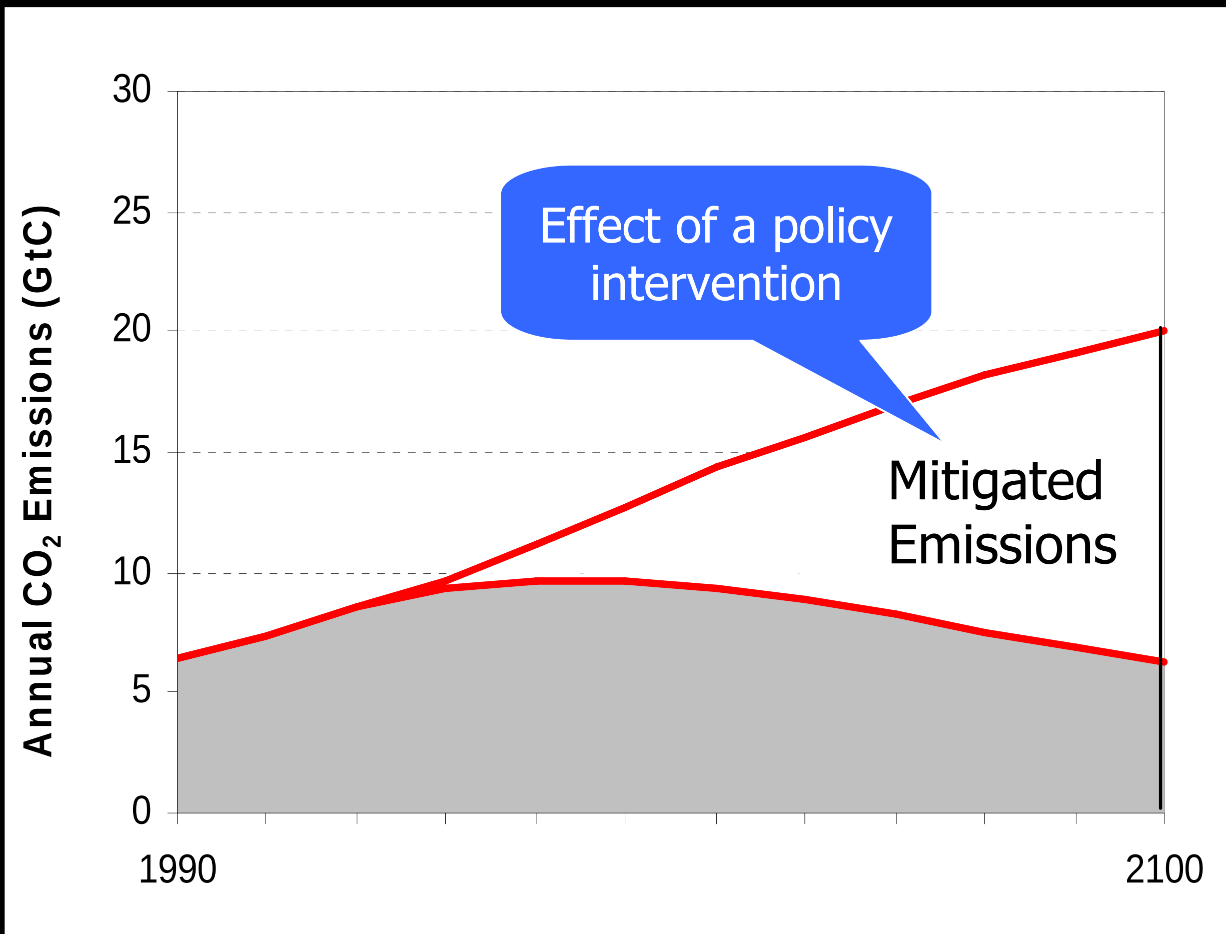
- What is the role of energy efficiency?
- Summary of findings, and your questions

Basic emissions scenario analysis



Emissions Profile of a Possible Future World

Basic emissions scenario analysis



Emissions Profile of a Possible Future World

Path to Stabilization

The Pervasive Scenario Intervention Policy

A uniform global carbon price

equal to the marginal cost of abatement

in a worldwide cap-and-trade program

with full participation, full flexibility, low transaction costs,

and *equal burden-sharing*.

Though this policy is not feasible to implement, it is used as a proxy:

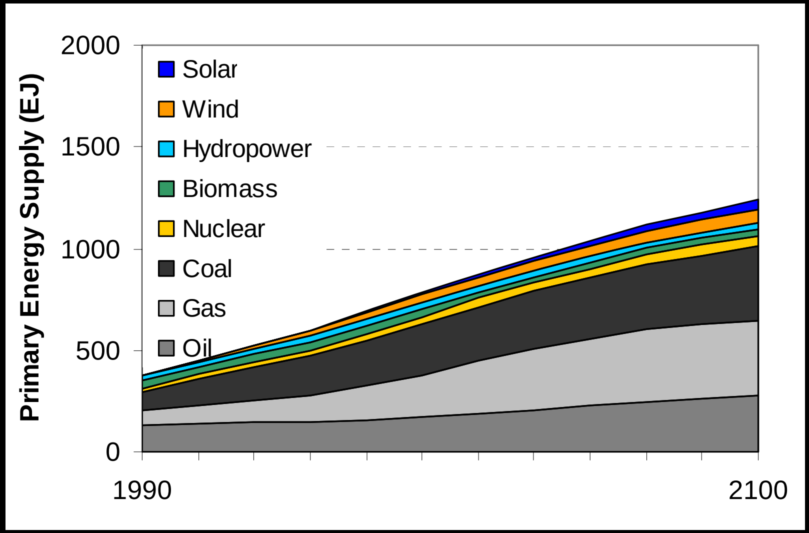
"A global uniform carbon price has been applied as a proxy of pressure on the system <u>to induce a variety of mitigation measures</u>."

- van Vuuren, RIVM 2001

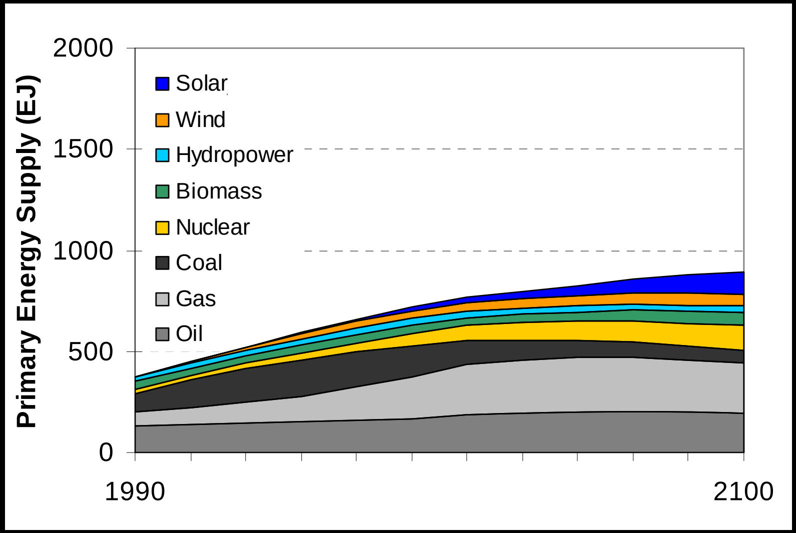
Changes to the Underlying Energy Sector

Primary Energy Resource Profile

Reference Case: "Before"



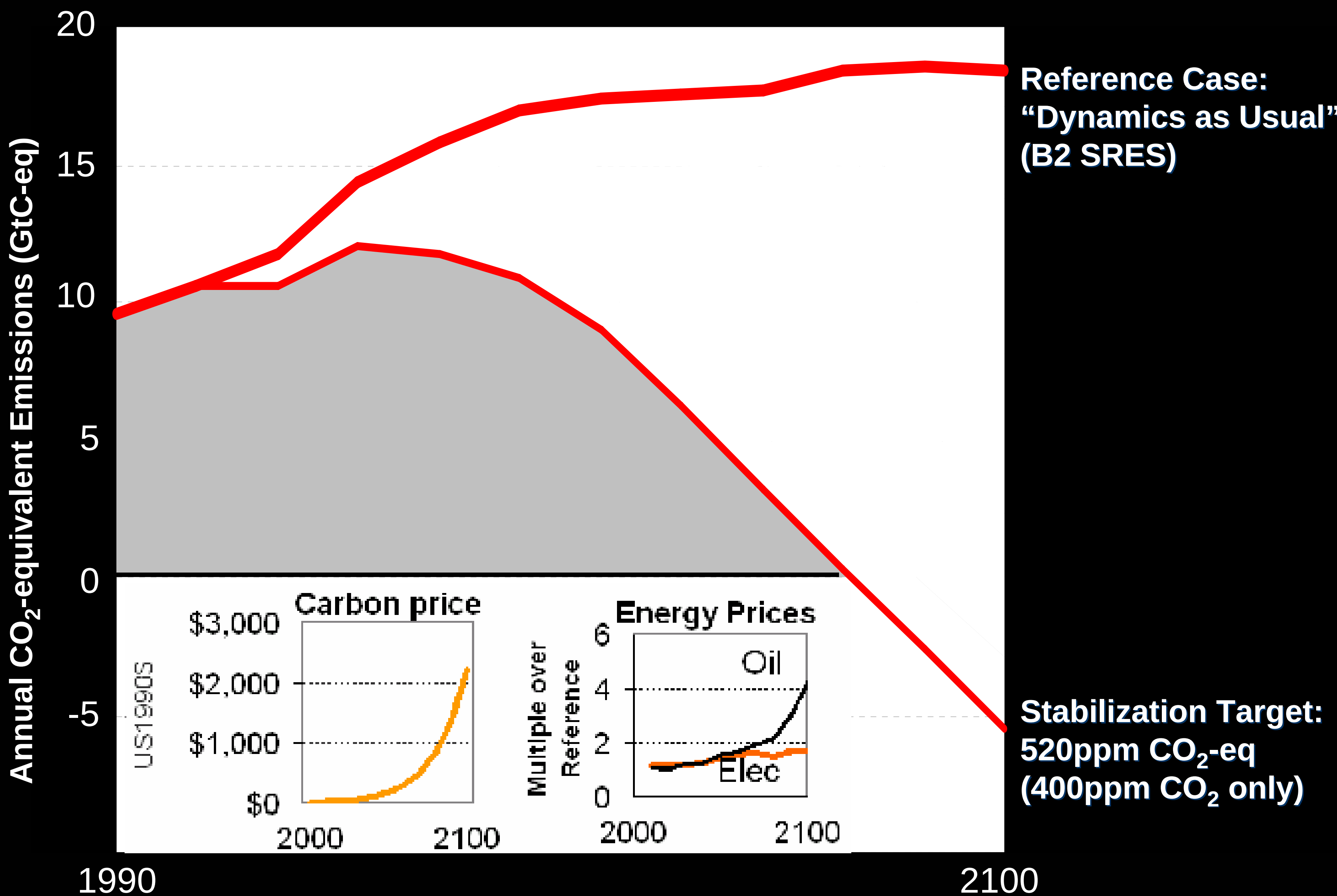
Mitigation Case: "After"



Moving beyond the familiar for more insight…

- *Lower demand*
- *Less coal*
- *…a breakthrough technology*

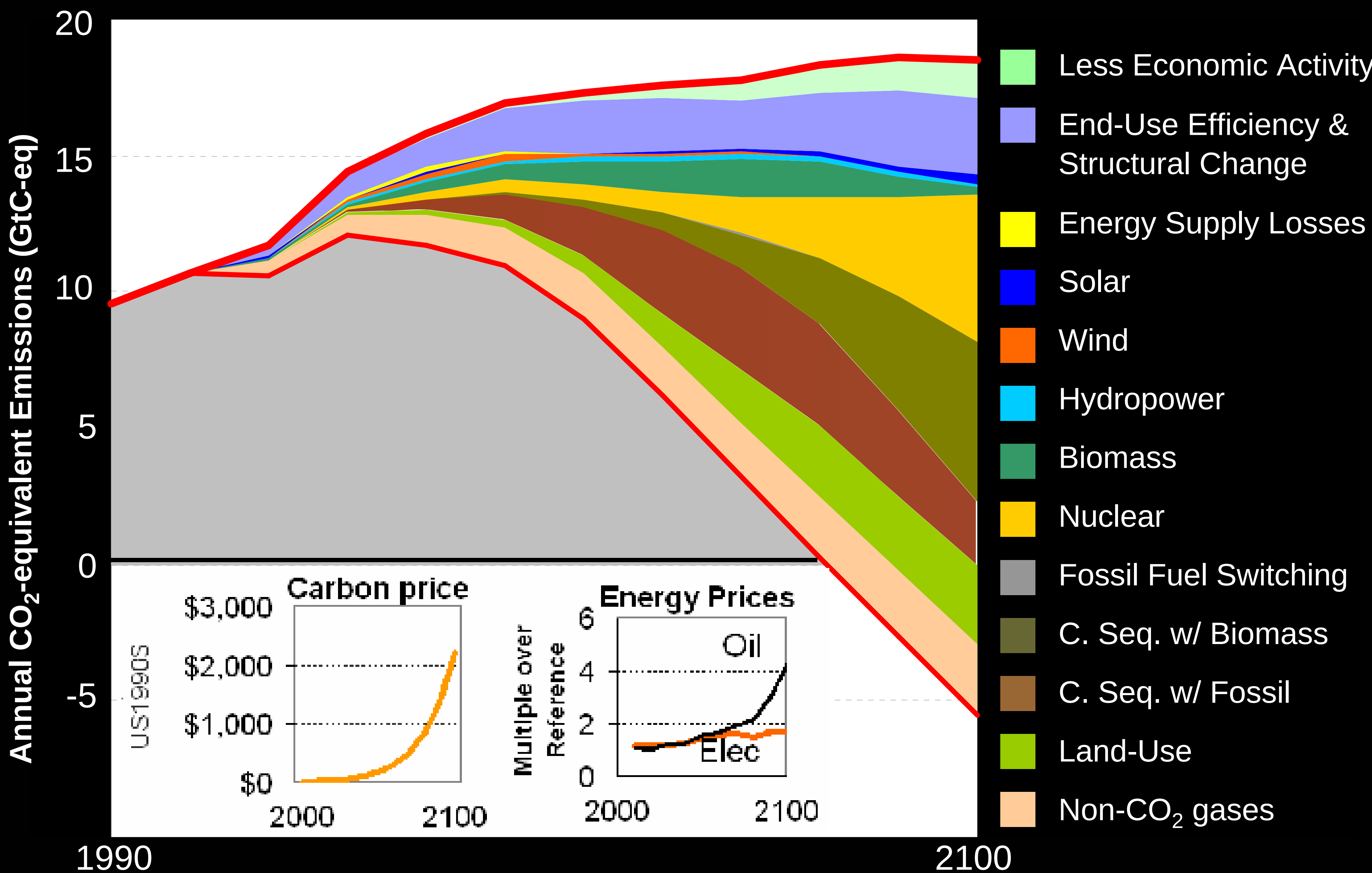
Decomposing Sources of Mitigation



Mid-range reference case (B2) limited to 520ppm CO2-eq (IIASA GGI, 2006)

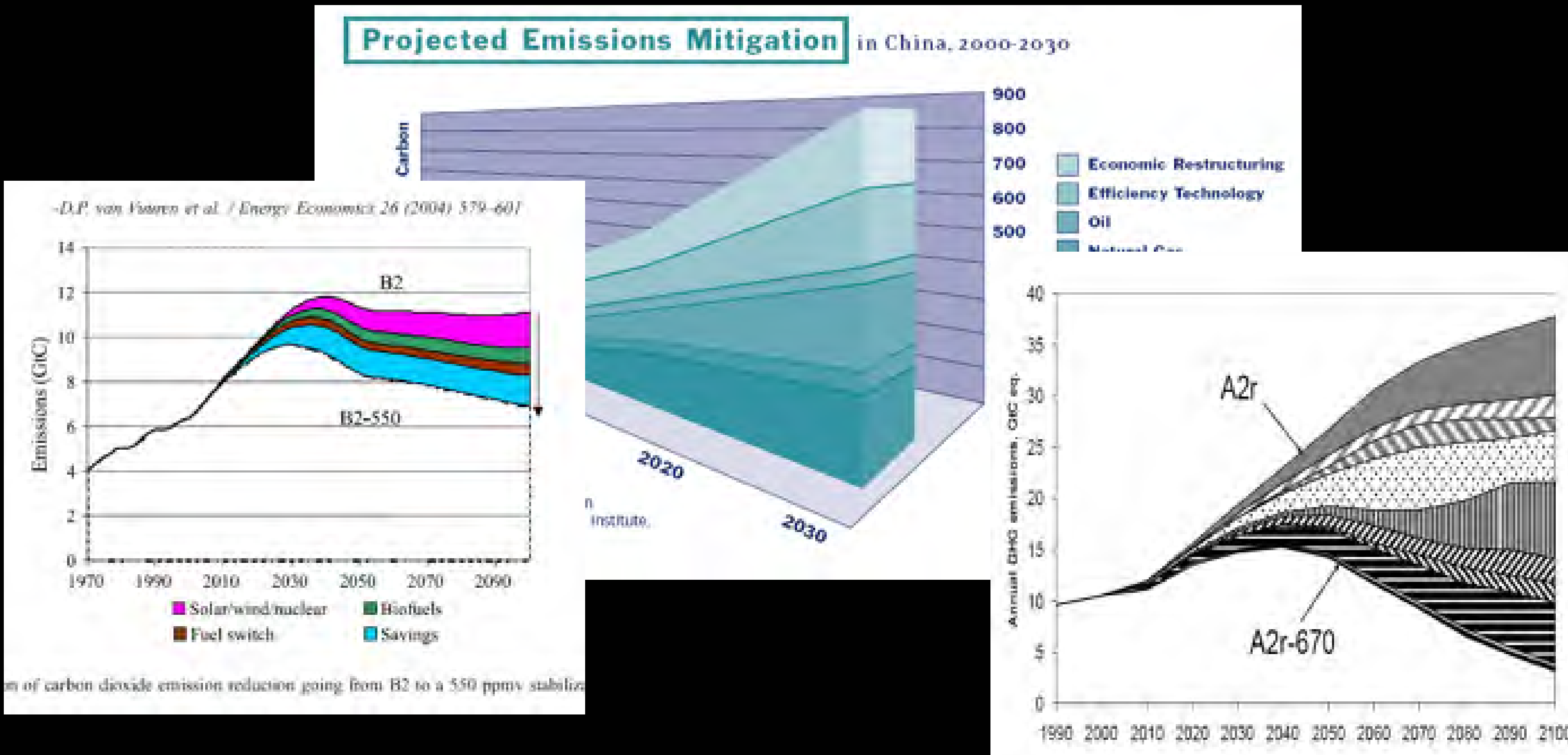
Model: MESSAGE-MACRO (IIASA GGI, 2006)

Decomposing Sources of Mitigation



Mid-range reference case (B2) limited to 520ppm CO2-eq (IIASA GGI, 2006)

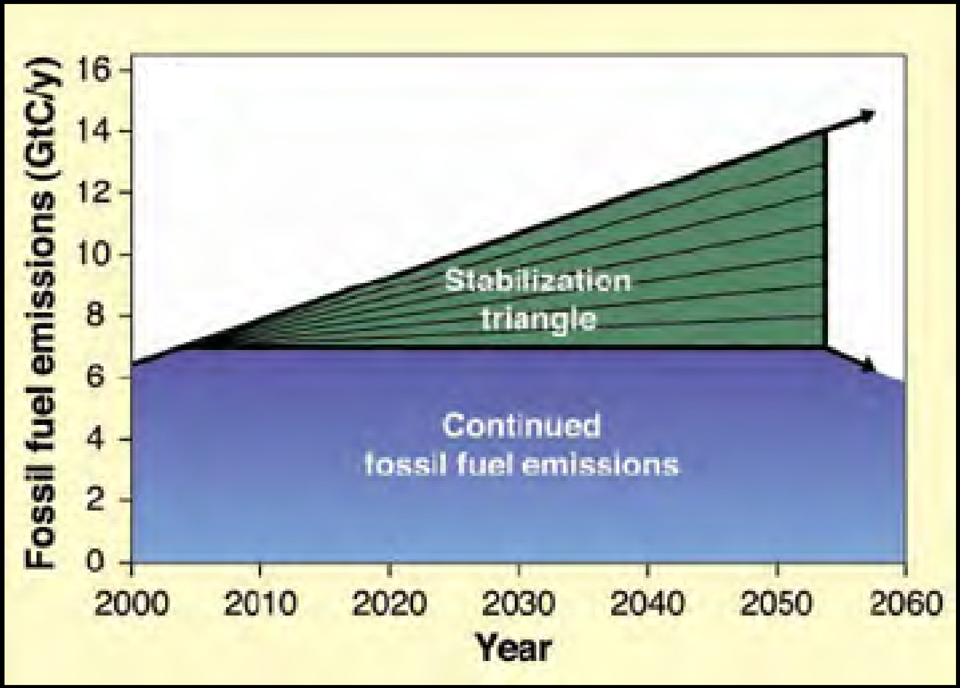
Three modeling teams have published decompositions of their scenario results, though not the algorithms used to make them.



Thus, the analysis is non-transferable and the results are incomparable.

The algorithm used here can be applied to any scenario for which sufficient energy data is disclosed.

Comparison with "stabilization wedges" concept



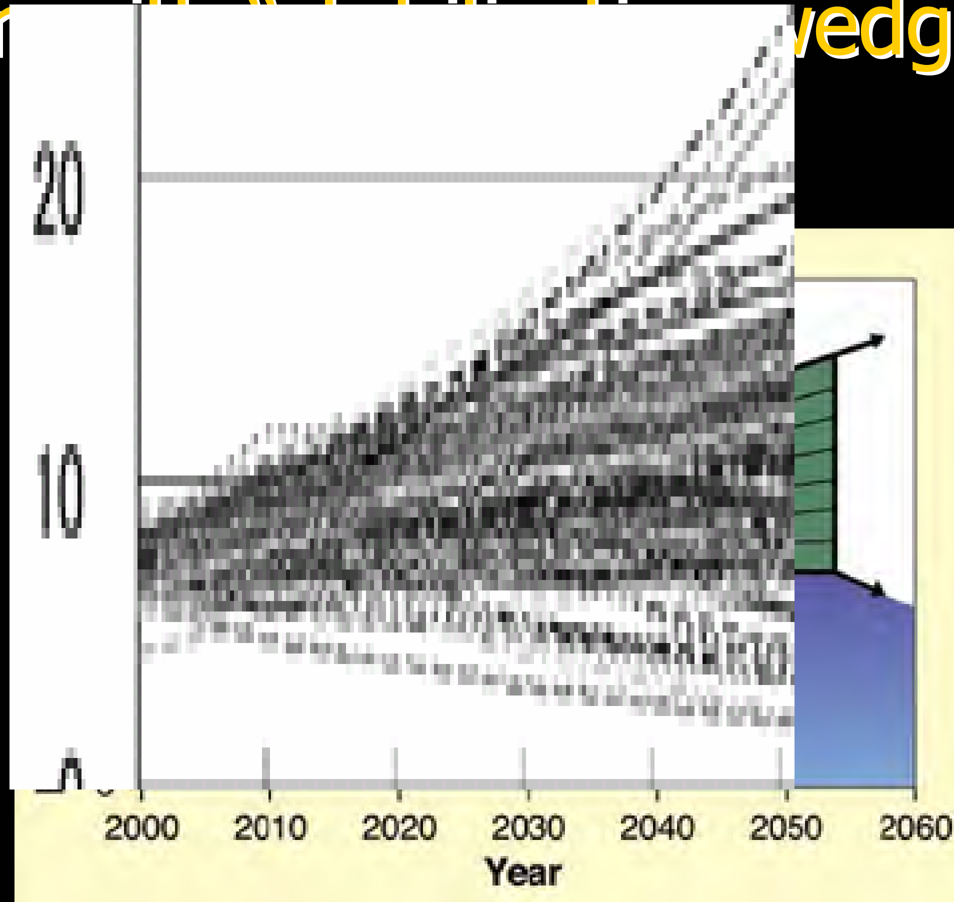
Pacala, S. and R. Socolow. 2004. "Stabilization Wedges," Science, Vol 305

Presents fixed reference and stabilization paths,

then offers mix & match technologies

in units of a "stabilization wedge" (25 GtC).

Comparison with “stabilization wedges” concept



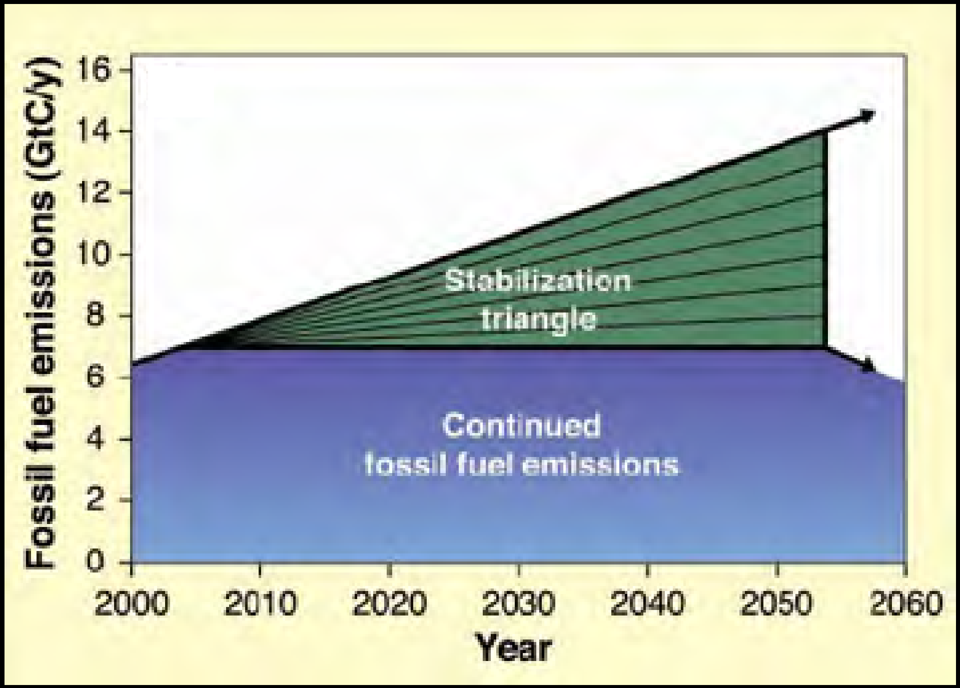
Pacala, S. and R. Socolow. 2004. “Stabilization Wedges,” Science, Vol 305
Hanaoka, et al. 2006. Greenhouse Gas Emissions Scenarios Database, NIES. (Fig 3.4)

Uncertainty is fundamental to the problem.

then offers mix & match technologies

in units of a “stabilization wedge” (25 GtC).

Comparison with "stabilization wedges" concept



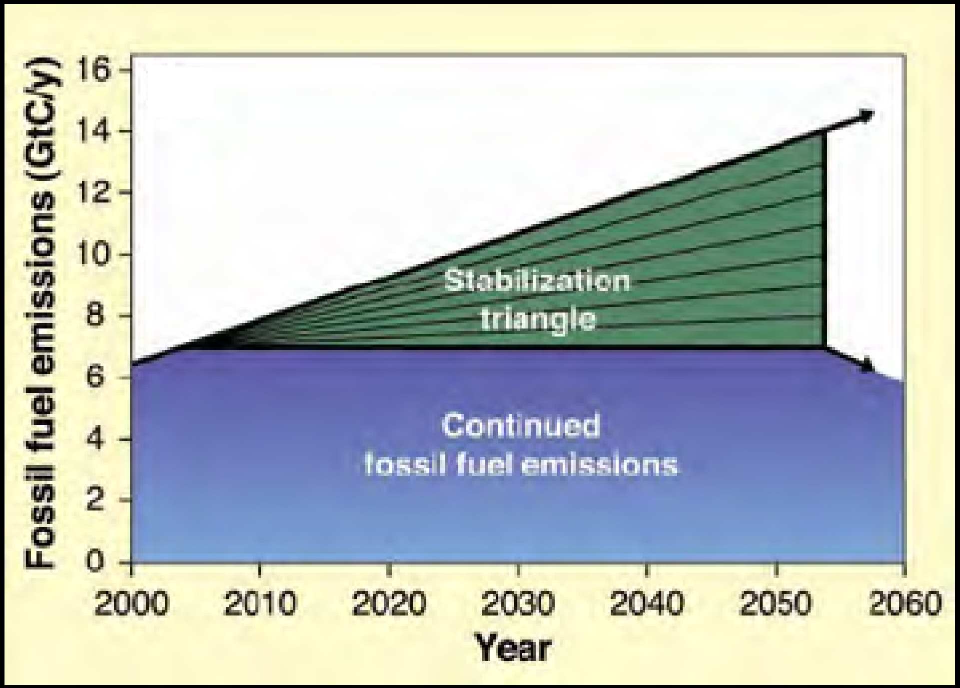
Pacala, S. and R. Socolow. 2004. "Stabilization Wedges," Science, Vol 305

Uncertainty is fundamental to the problem.

Technological innovation paths are interdependent.

in units of a "stabilization wedge" (25 GtC).

Comparison with "stabilization wedges" concept



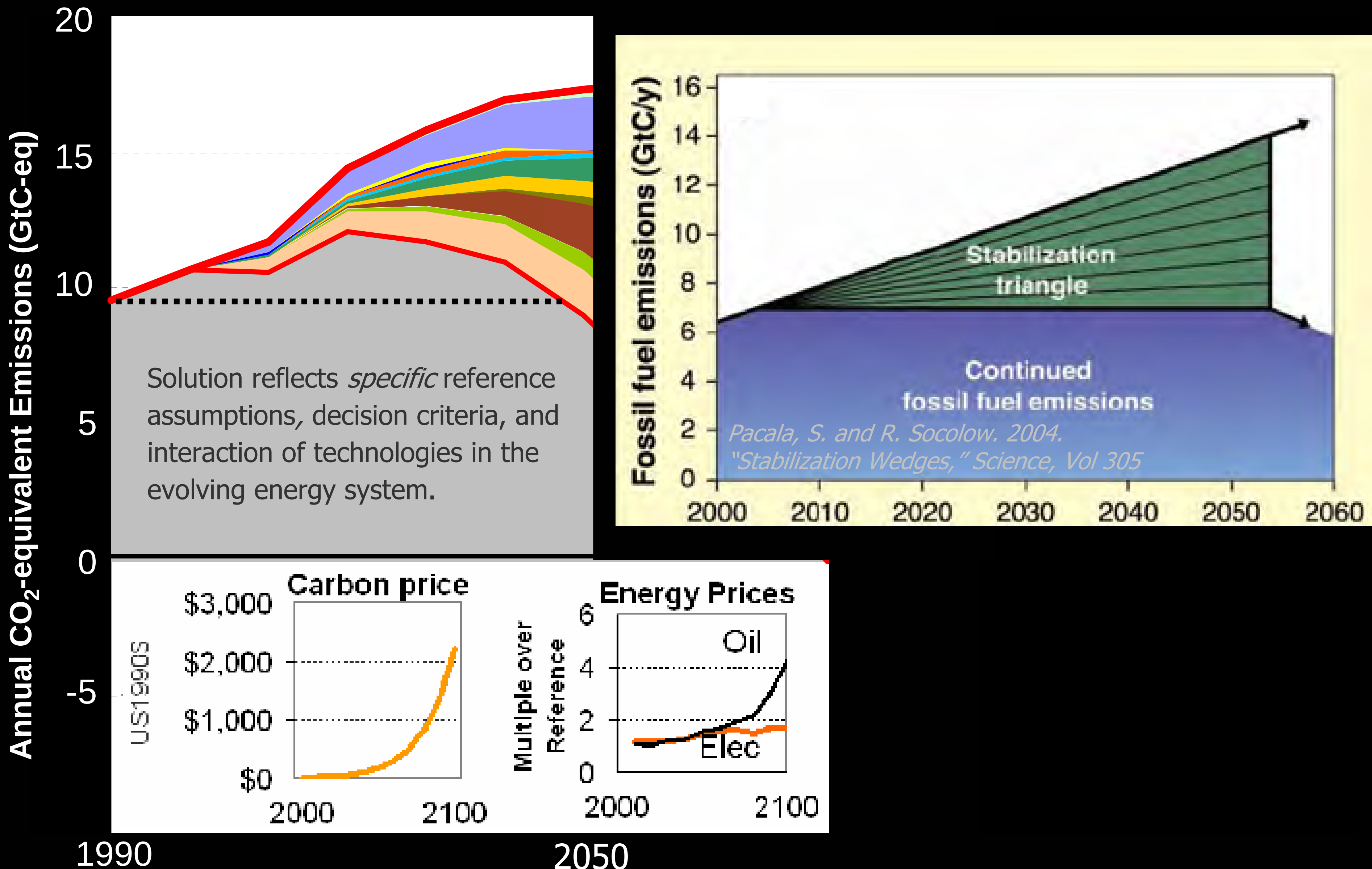
Pacala, S. and R. Socolow. 2004. "Stabilization Wedges," Science, Vol 305

Uncertainty is fundamental to the problem.

Technological innovation paths are interdependent.

Proportion and timing of mitigation measures matter.

Comparison with “stabilization wedges” concept



Mid-range reference case (B2) limited to 520ppm CO2-eq (GGI, 2006)

Exploring Energy Futures

model agnostic

- Constructing a common framework for interpretation
  - How do policy interventions affect key drivers of emissions?
  - What are the sources of mitigation in stabilization scenarios?
  - Accounting for direct equivalent energy accounting
- Insights from analyzing several widely-cited energy scenarios
- What is the role of energy efficiency?
- Summary of findings, and your questions

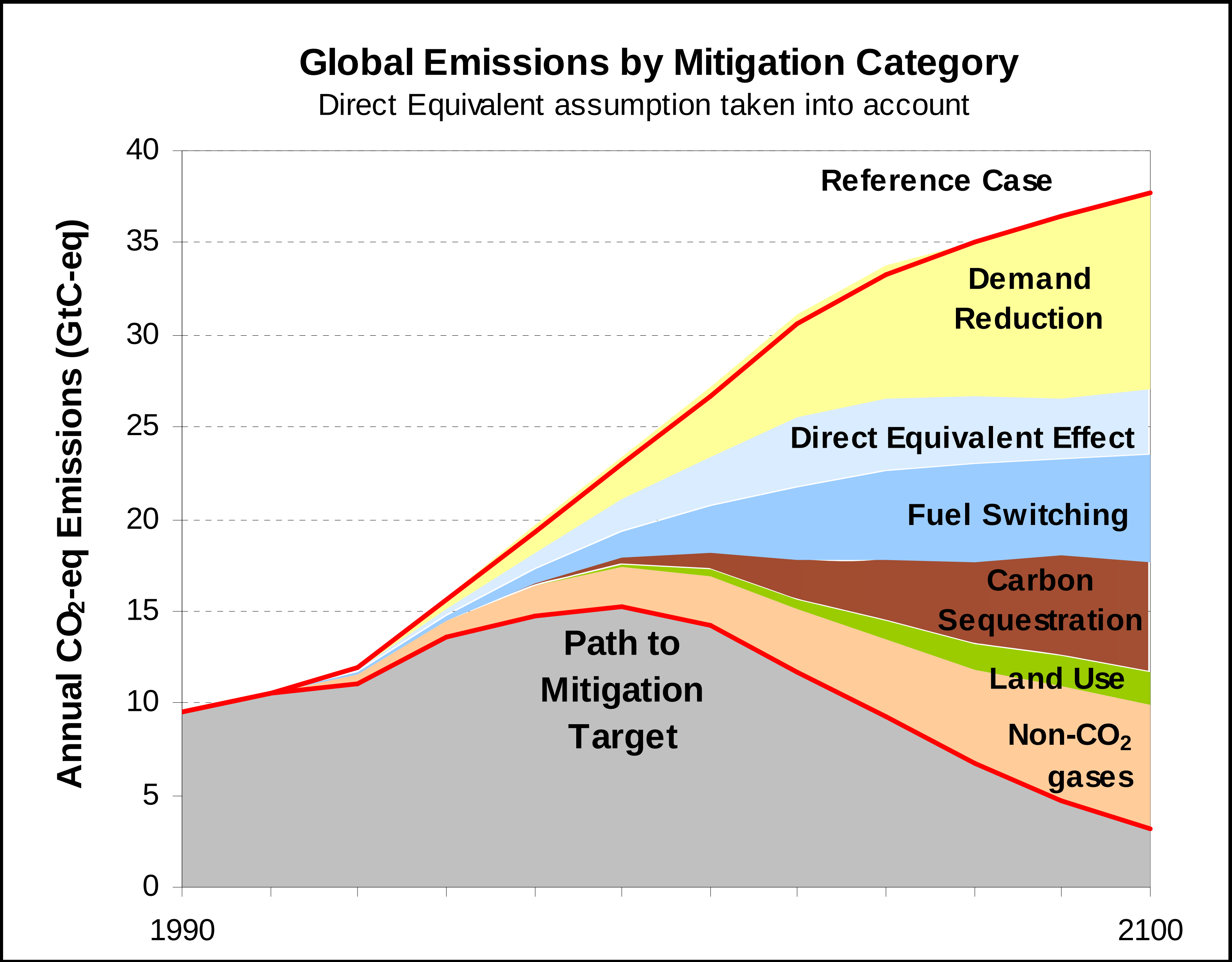
Accounting for the Direct Equivalent method

- Primary energy accounting affects results of both the decomposition of key drivers and the decomposition of mitigation sources, and must be taken into account.

- The direct equivalent method sets primary energy directly equal to the heat content of delivered final energy – giving appearance of 100% efficiency.

- The scale of the distortion increases as more solar, hydro, and wind power displace fossil fuels. IPCC SRES scenarios treat nuclear power as a direct equivalent source as well.

- Use of data based on the direct equivalent method will result in inflated indicators for efficiency, overestimating actual reduction in demand.



High Growth (A2r GGI), Stabilization: 670ppm CO_2-eq, Model: MESSAGE-MACRO

Exploring Energy Futures

model agnostic

- Constructing a common framework for interpretation
  - How do policy interventions affect key drivers of emissions?
  - What are the sources of mitigation in stabilization scenarios?
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- What is the role of energy efficiency?
- Summary of findings, and your questions

Data

Summary data for 700+ scenarios

NIES Database

Detailed stabilization scenarios

Criteria for sample scenarios:

- ✓ Energy system detail
- ✓ At least three different models
- ✓ Accessible data
- ✓ Multiple reference cases
- ✓ (Relatively) Low stabilization levels

Sample Stabilization Scenarios

Scenario Study	Reference Case	Stabilization Case	Model
EMF-19	B2	550 CO2	MiniCAM
EMF-19	B2	550 CO2	IMAGE
EMF-19	B2	550 CO2	MSG-MCR
WBGU	A1T*	450 CO2	MSG-MCR
WBGU	B1*	400 CO2	MSG-MCR
IPCC TAR	A2	550 CO2	MSG-MCR
GGI	A2	670 CO2 eq	MSG-MCR
GGI	B2	480 CO2 eq	MSG-MCR
GGI	B1	480 CO2 eq	MSG-MCR
MNP	B1	400 CO2	IMAGE
IPCC TAR	A1B	550 CO2	IMAGE

Multiple reference cases

(Relatively) Low Stabilization targets

Multiple models

Sample Stabilization Scenarios

	Scenario Study	Reference Case	Stabilization Case	Model
①	EMF-19	B2	550 CO2	MiniCAM
	EMF-19	B2	550 CO2	IMAGE 2.2
	EMF-19	B2	550 CO2	MSG-MCR
②	WBGU	A1T*	450 CO2	MSG-MCR
	WBGU	B1*	400 CO2	MSG-MCR
③	IPCC TAR	A2	550 CO2	MSG-MCR
	GGI	A2	670 CO2 eq	MSG-MCR
④	GGI	B2	520 CO2 eq	MSG-MCR
⑤	GGI	B1	480 CO2 eq	MSG-MCR
	MNP	B1	450 CO2	IMAGE 2.2

Common: Reference case & Stabilization target
Different: Model & Technology assumptions

Reference
Stabilization targets
Model
Technology assumptions

Reference case *
Stabilization target
Model
Technology assumptions

Reference
Stabilization targets
Model
Technology assumptions

Two “low-low” scenarios

Impact of model & modeler assumptions:

Same reference & stabilization target

Different models & technology assumptions

Reference: "Dynamics as Usual" (B2 SRES)

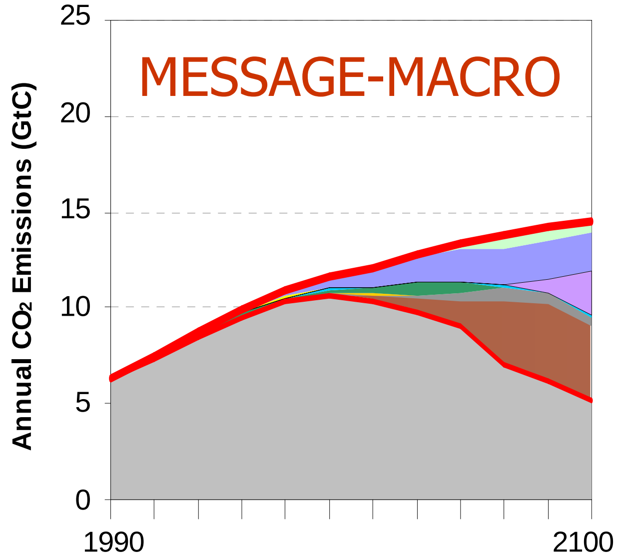
Mitigation Target: 550ppm CO_2 (doubling of pre-industrial levels)

Study: Energy Modeling Forum, Study #19

Impact of model & modeler assumptions:

Same reference & stabilization target

Different models & technology assumptions



Decomposition of: Riahi et al, 2004

Reference: "Dynamics as Usual" (B2 SRES)

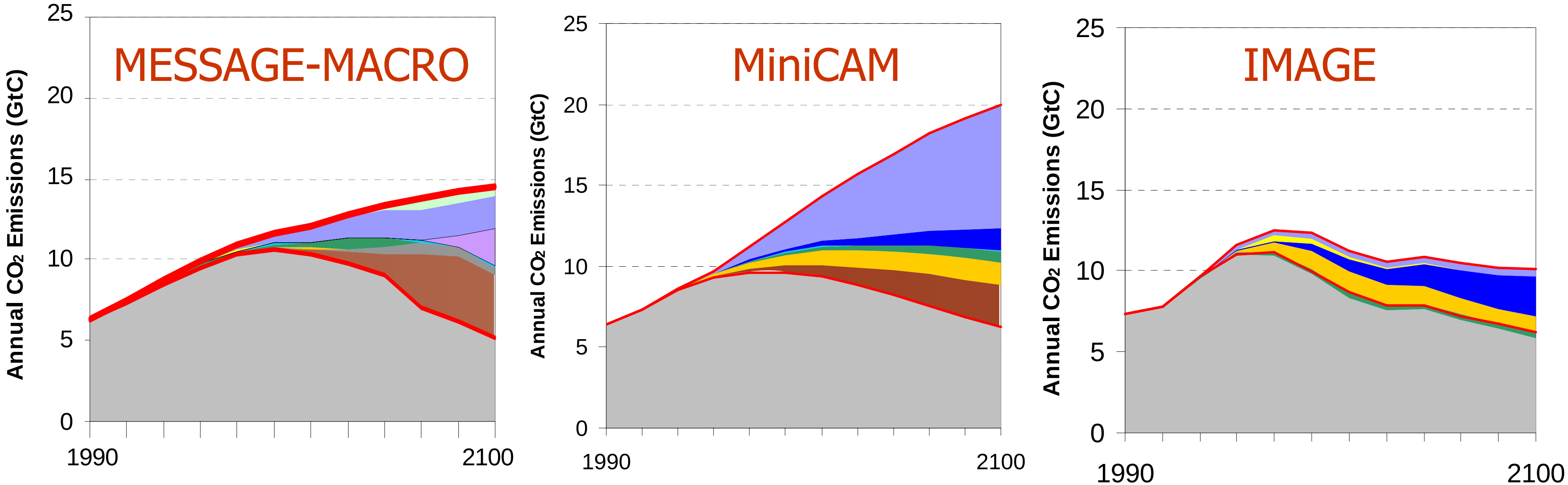
Mitigation Target: 550ppm CO_2 (doubling of pre-industrial levels)

Study: Energy Modeling Forum, Study #19

Impact of model & modeler assumptions:

Same reference & stabilization target

Different models & technology assumptions



Decomposition of: Riahi et al, 2004 Edmonds et al, 2004 van Vuuren et al, 2004

Reference: "Dynamics as Usual" (B2 SRES)

Mitigation Target: 550ppm CO_2 (doubling of pre-industrial levels)

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Impact of model & modeler assumptions:

Same reference & stabilization target

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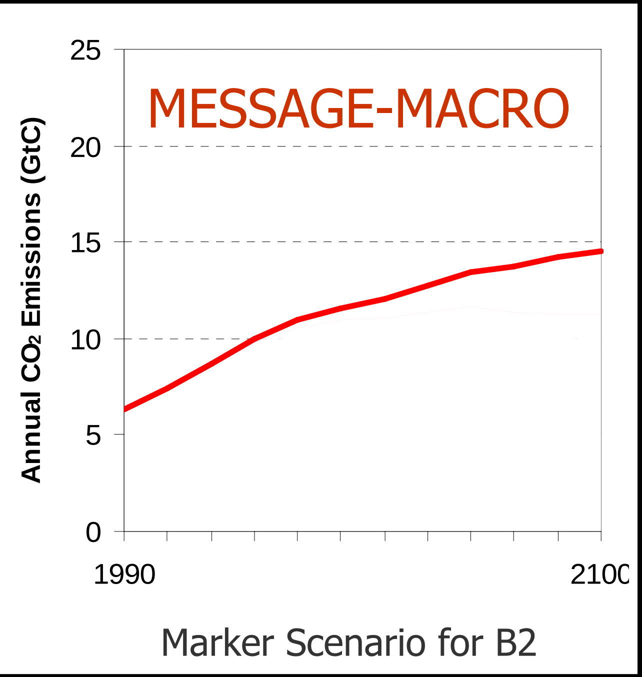
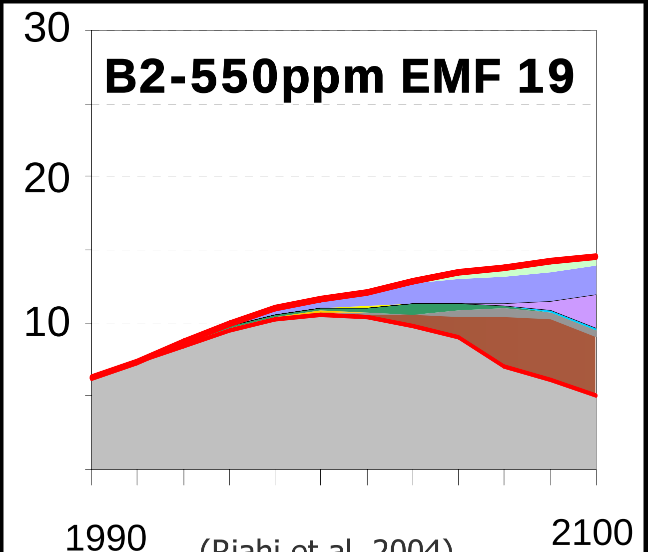


Impact of Technology Assumptions:

Same Model (MESSAGE-MACRO, 2000-2004)

Different Reference cases & Stabilization targets

Annual CO_2 Emissions (GtC)

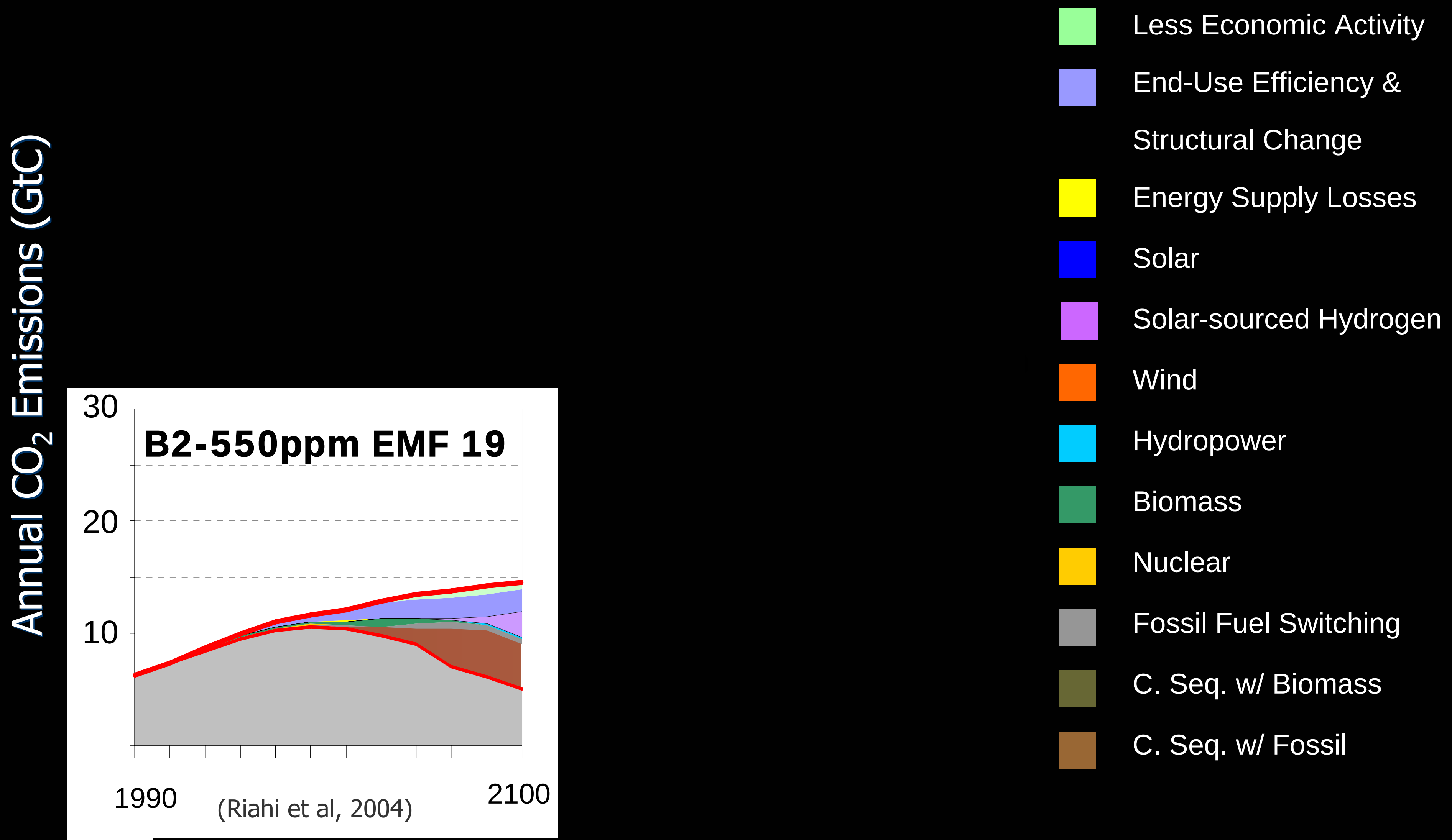


(Riahi et al, 2004)

Impact of Technology Assumptions:

Same Model (MESSAGE-MACRO, 2000-2004)

Different Reference cases & Stabilization targets



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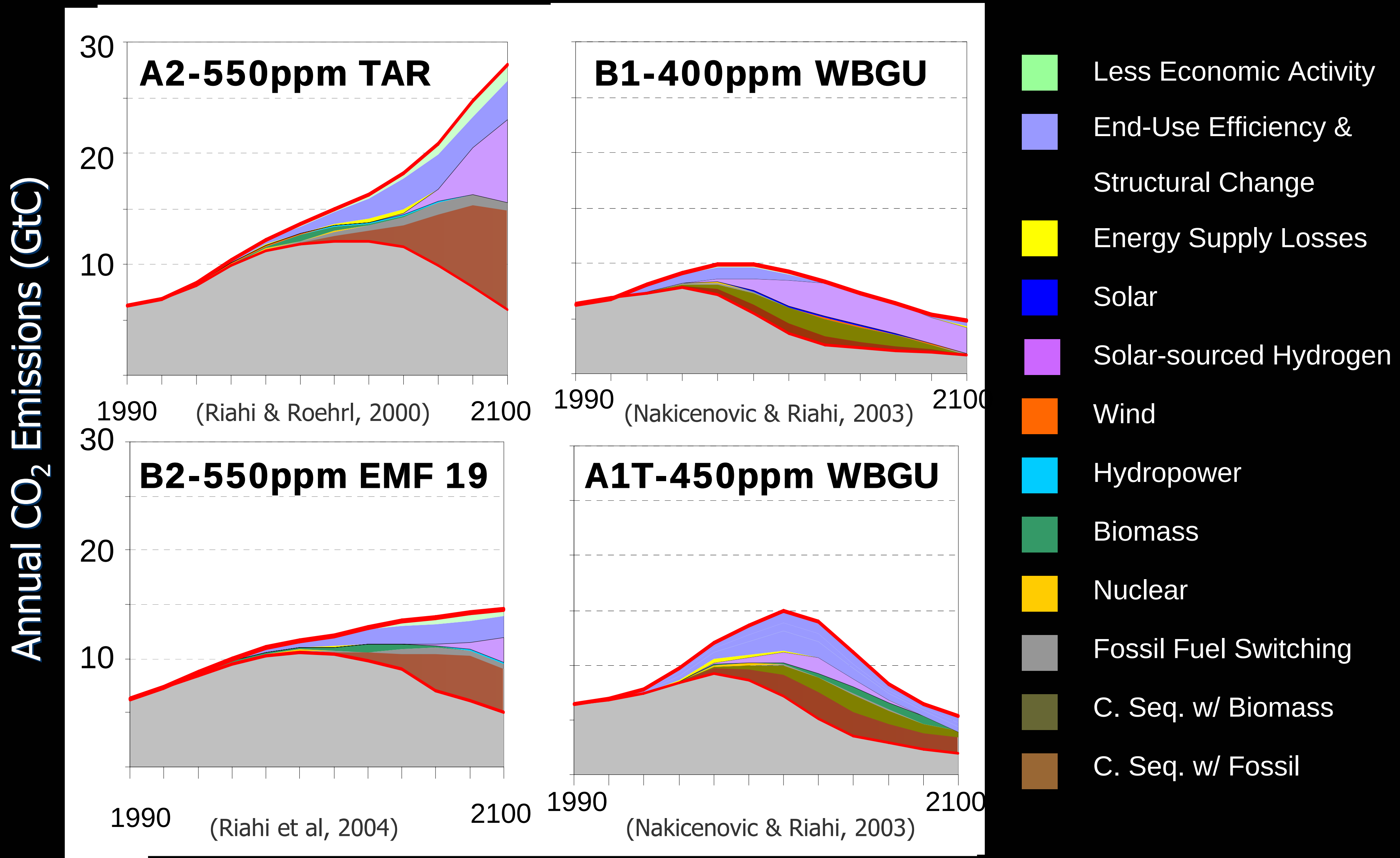
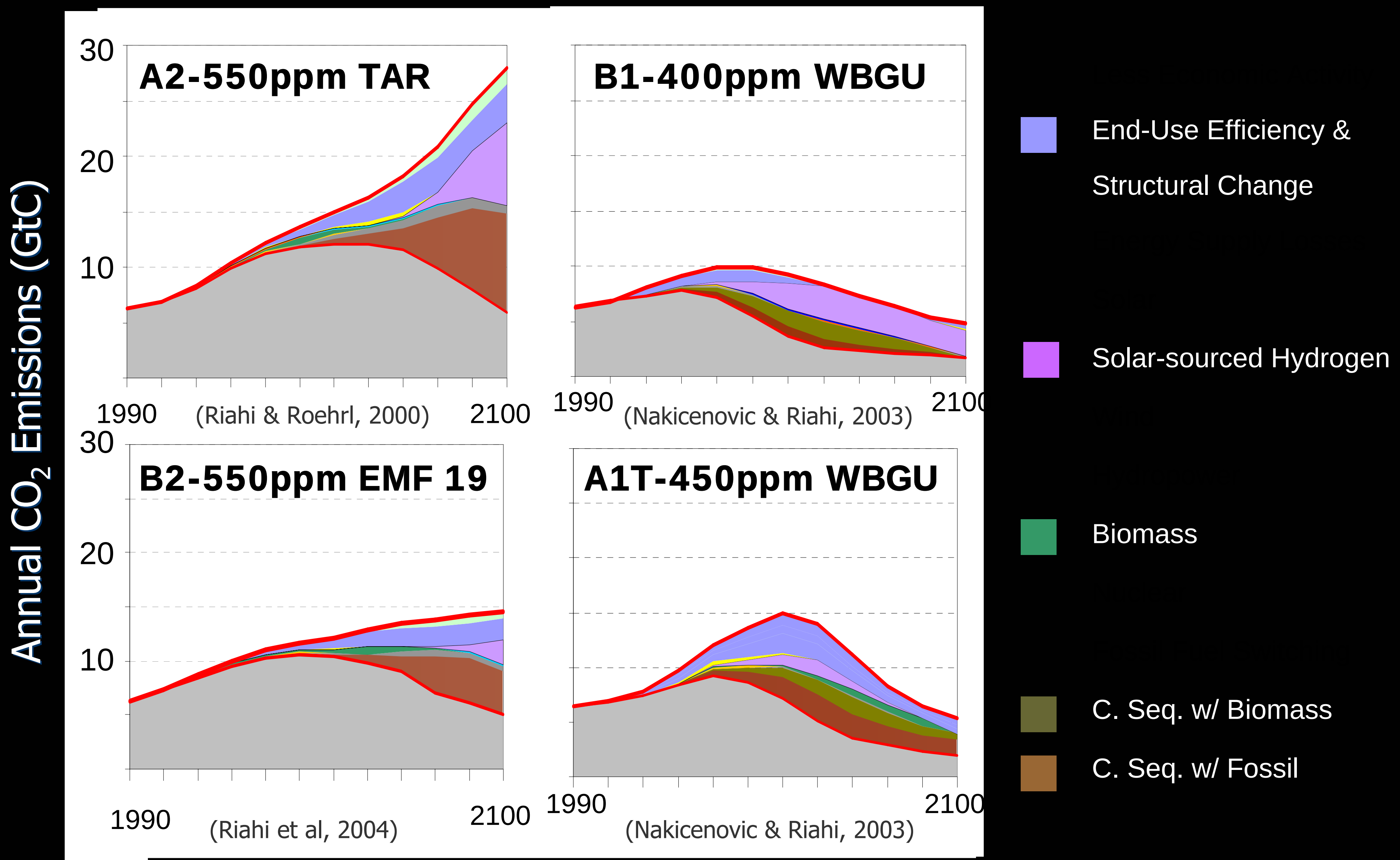


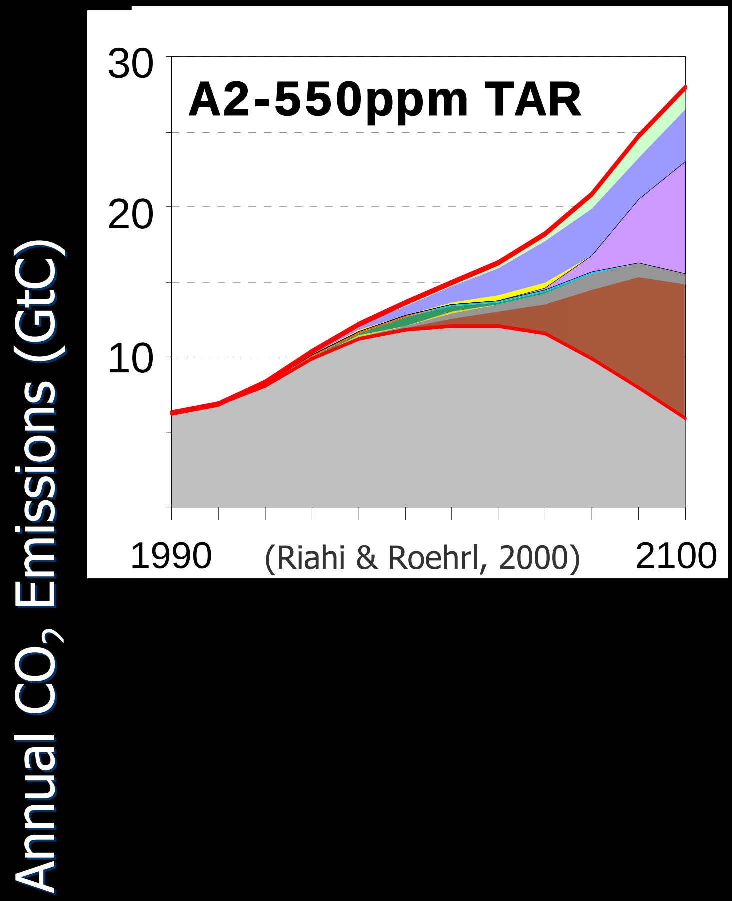
Impact of Technology Assumptions:

Same Model (MESSAGE-MACRO, 2000-2004)

Different Reference cases & Stabilization targets

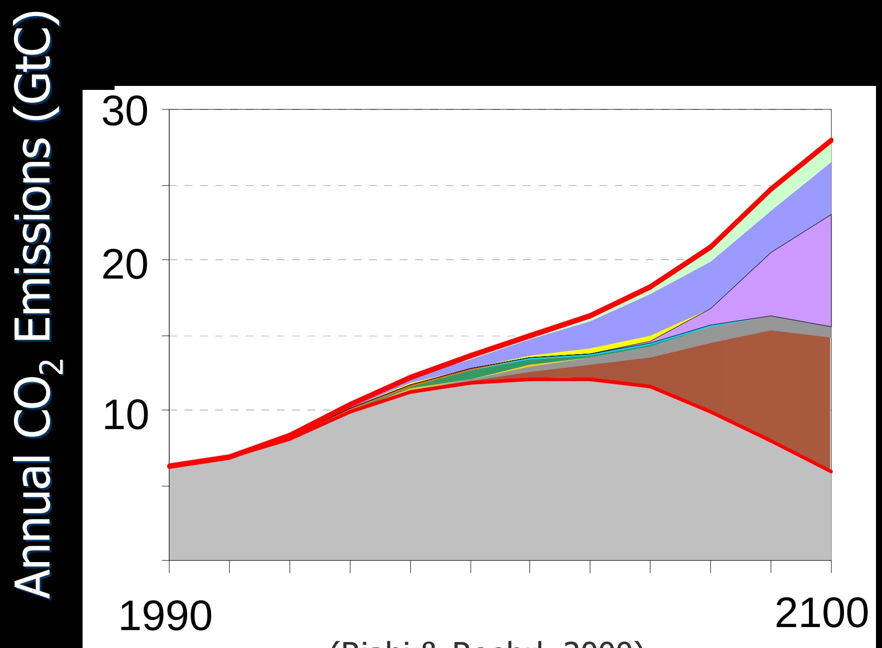


Impact of Technology Assumptions:
Same Model (MESSAGE-MACRO, 2000-2004)
Different Reference cases & Stabilization targets



Impact of technology assumptions:

Similar high growth reference case and stabilization target from the same model with different technology assumptions

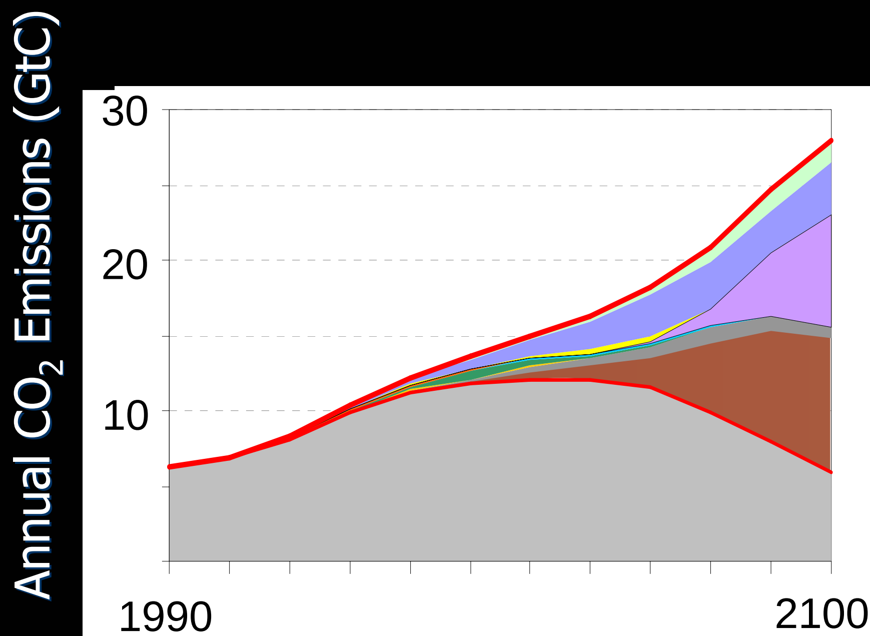


(Riahi & Roehrl, 2000)

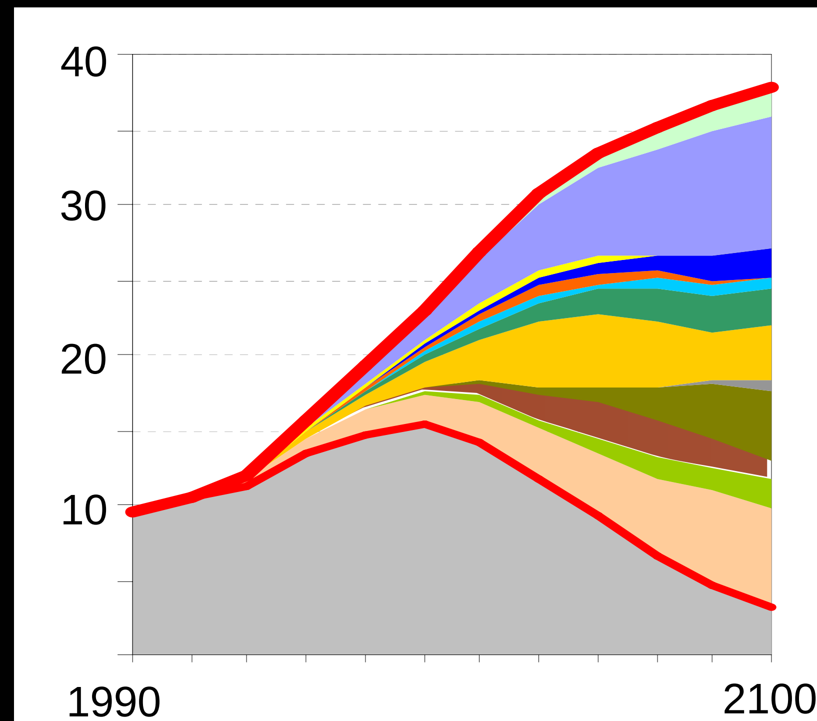
Reference: A2 (SRES)
Target: 550 ppm CO_2 only
Model: MESSAGE-MACRO

Impact of technology assumptions:

Similar high growth reference case and stabilization target from the same model with different technology assumptions



(Riahi & Roehrl, 2000)



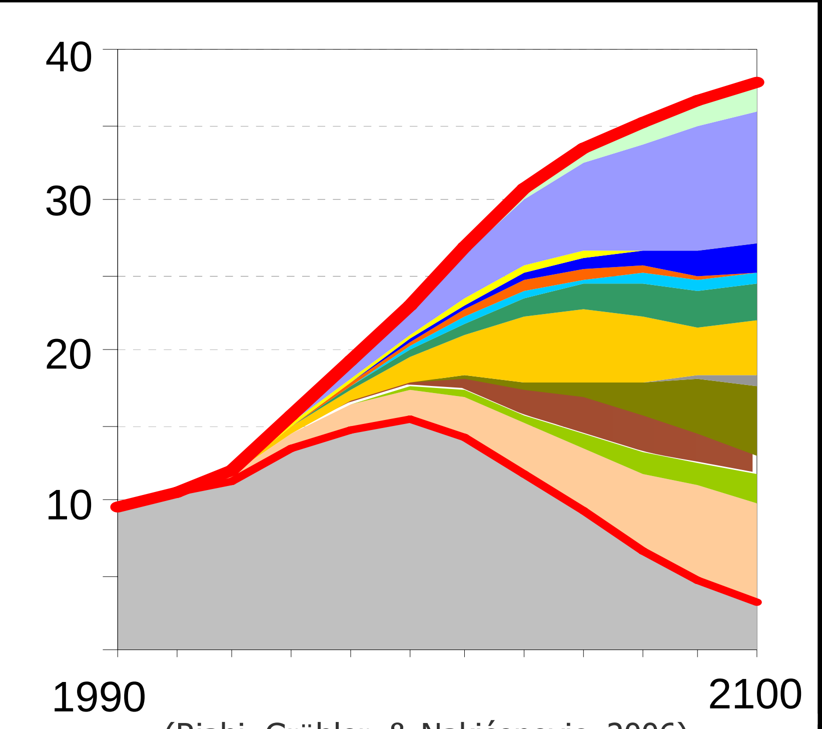
(Riahi, Grübler, & Nakićenovic, 2006)

Reference: A2 (SRES)
Target: 550 ppm CO_2 only
Model: MESSAGE-MACRO

Reference: A2 (SRES) multi-gas
Target: 4.5 W/m² (670ppm CO_2-eq) multi-gas
Model: MESSAGE-MACRO

Impact of technology assumptions:

Similar high growth reference case and stabilization target from the same model with different technology assumptions



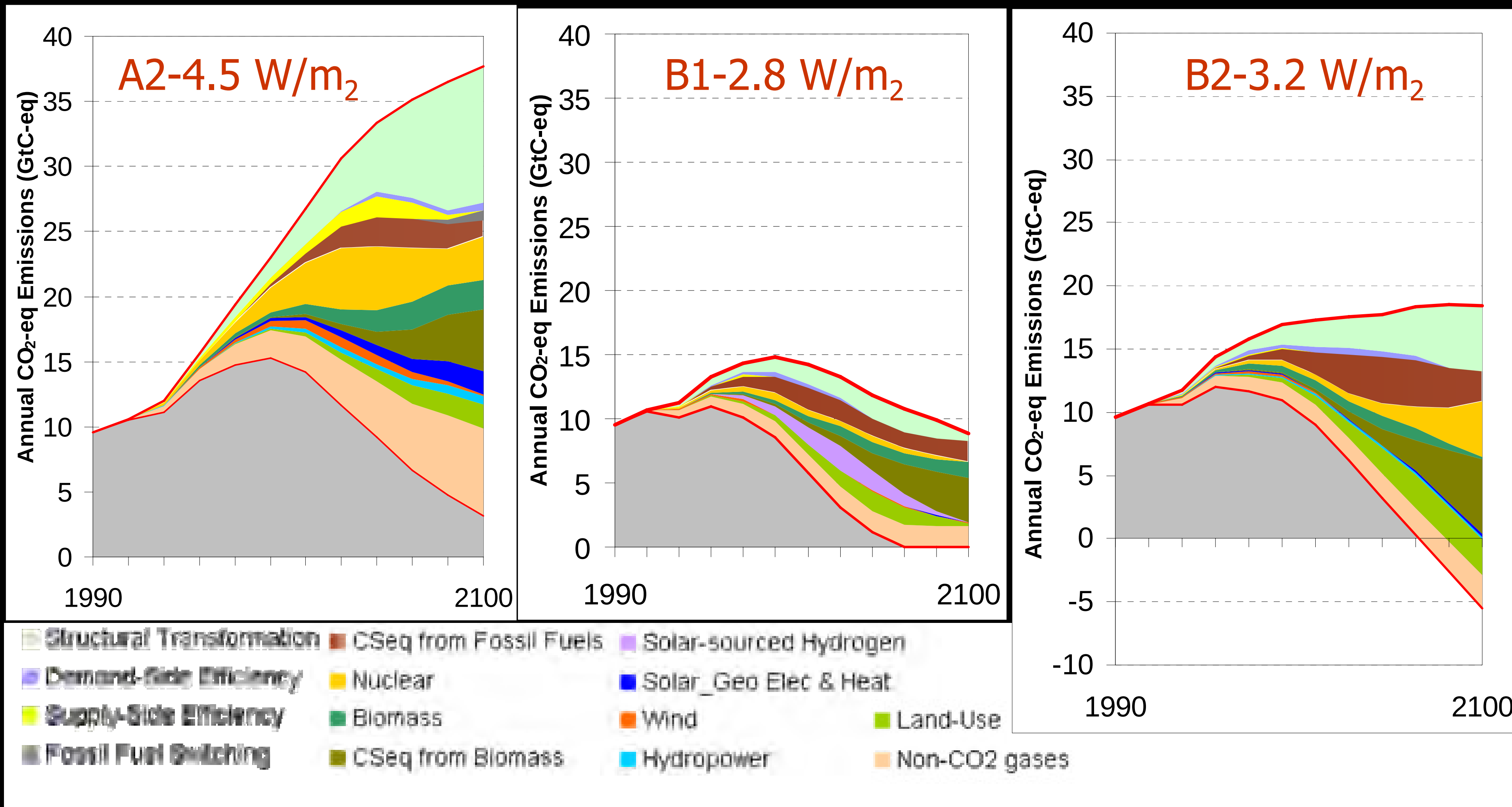
(Riahi, Grübler, & Nakićenovic, 2006)

Reference: A2 (SRES) multi-gas
Target: 4.5 W/m² (670ppm CO_2-eq) multi-gas
Model: MESSAGE-MACRO

Impact of scenario assumptions:

Same model & similar technology assumptions

Different reference cases & stabilization targets



MESSAGE-MACRO scenarios by IIASA Greenhouse Gas Initiative

Exploring Energy Futures

model agnostic

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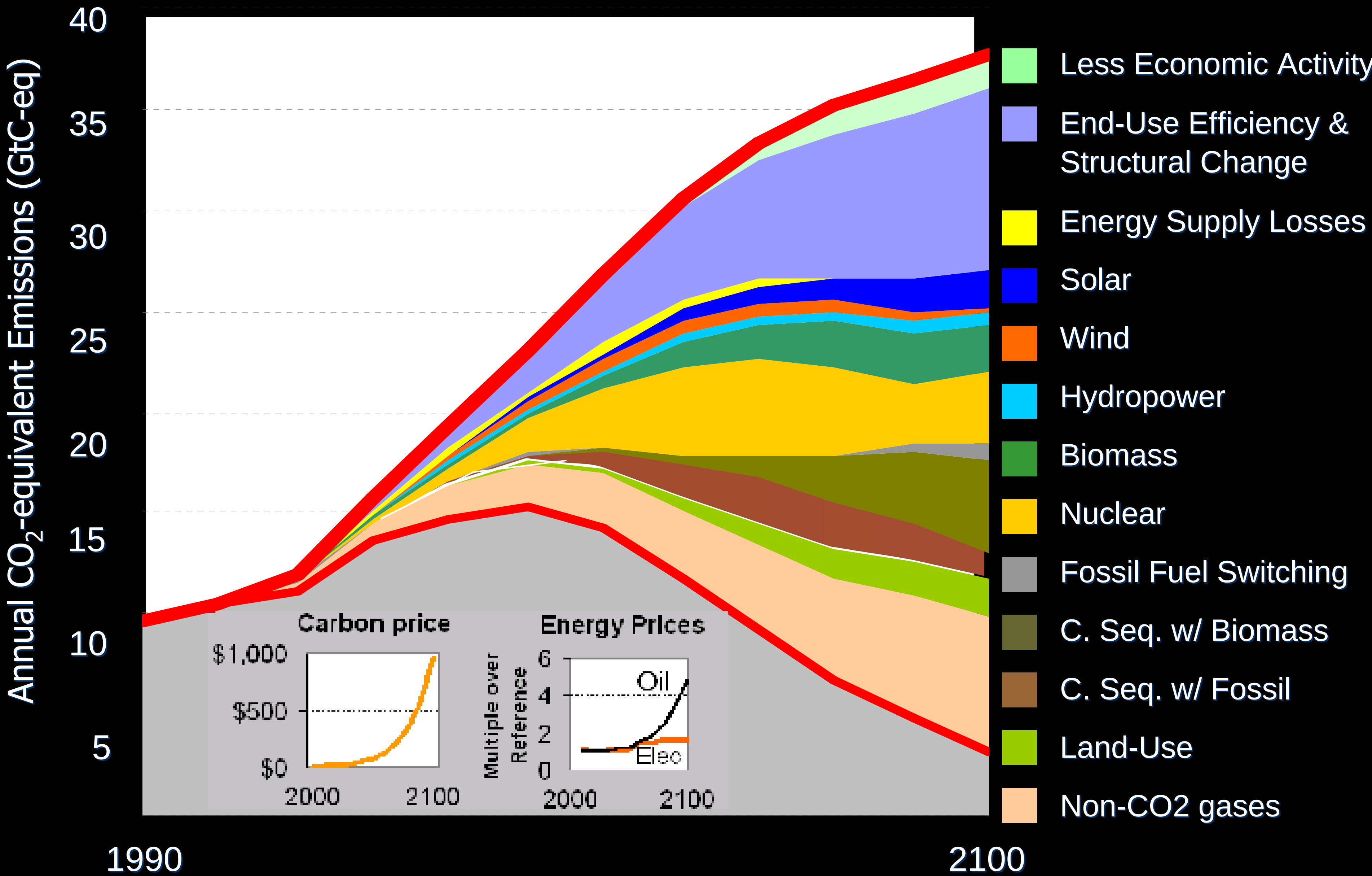
Examining the Role of Efficiency

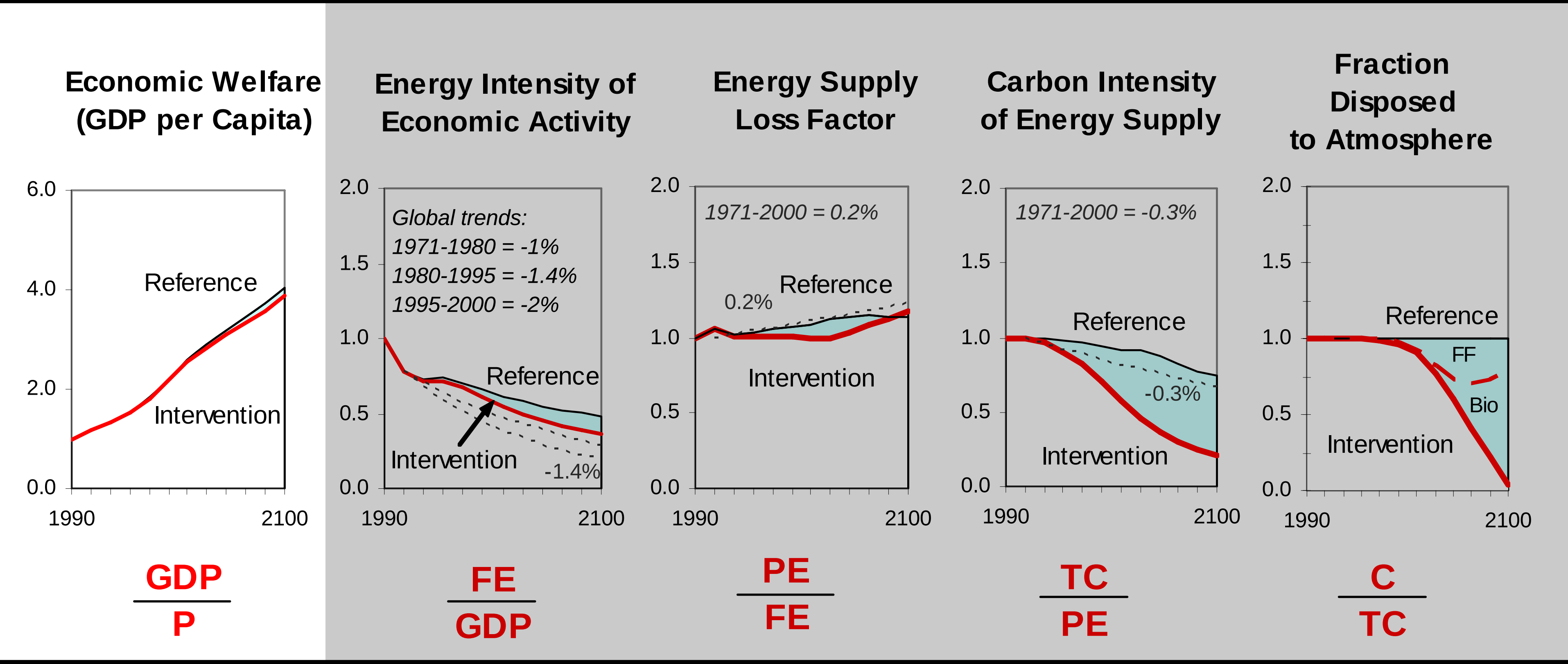


High growth reference case (A2) limited to 670ppm CO2-eq (MSG-MACRO, IIASA GGI, 2006)

Examining the Role of Efficiency

Economic Welfare (GDP per Capita)	Energy Intensity of Economic Activity	Energy Supply Loss Factor	Carbon Intensity of Energy Supply	Fraction Disposed to Atmosphere
$\frac{GDP}{P}$	$\frac{FE}{GDP}$	$\frac{PE}{FE}$	$\frac{TC}{PE}$	$\frac{C}{TC}$

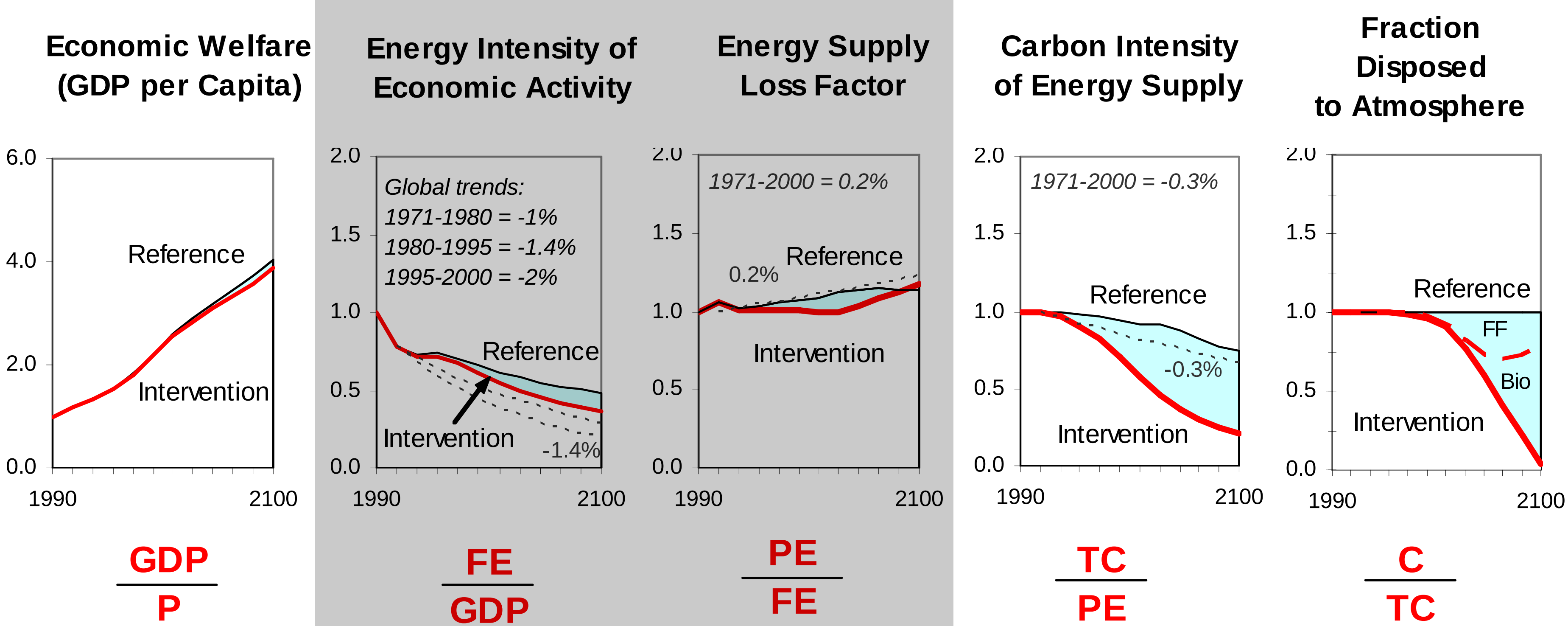
Examining the Role of Efficiency



Indexed to 1990=1

High growth reference case (A2) limited to 670ppm CO2-eq (MSG-MACRO, IIASA GGI, 2006)

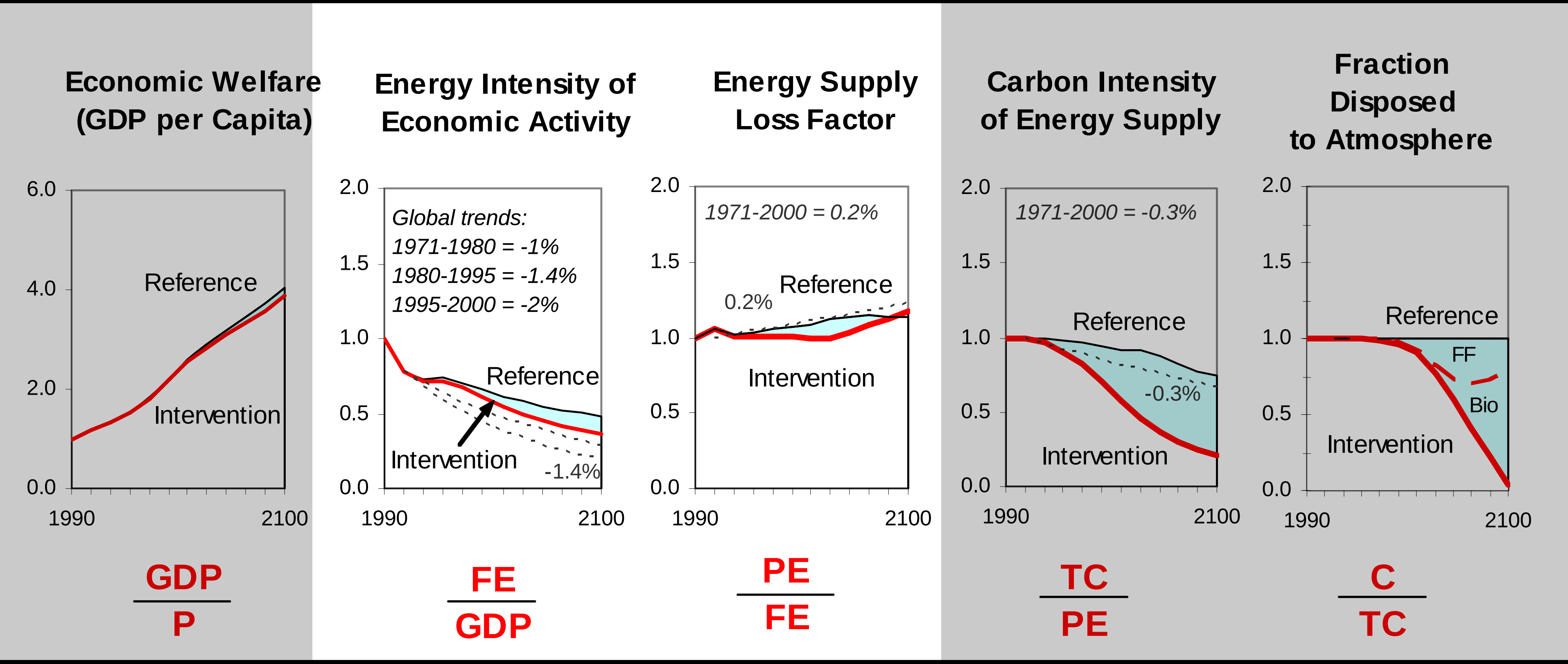
Examining the Role of Efficiency



Indexed to 1990=1

High growth reference case (A2) limited to 670ppm CO2-eq (MSG-MACRO, IIASA GGI, 2006)

Examining the Role of Efficiency

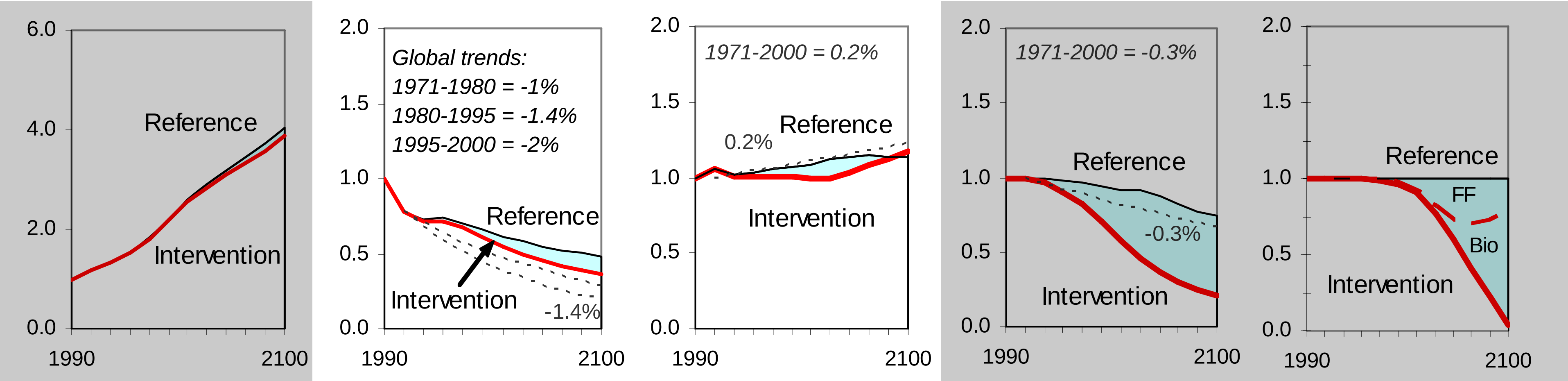


Indexed to 1990=1

High growth reference case (A2) limited to 670ppm CO2-eq (MSG-MACRO, IIASA GGI, 2006)

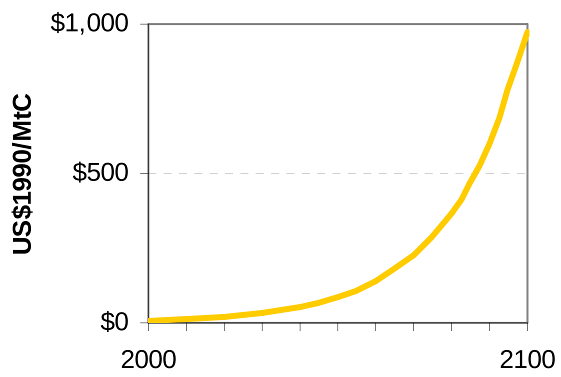
Examining the Role of Efficiency

Economic Welfare (GDP per Capita) | **Energy Intensity of Economic Activity** | **Energy Supply Loss Factor** | **Carbon Intensity of Energy Supply** | **Fraction Disposed to Atmosphere**



$\frac{GDP}{P}$ $\frac{FE}{GDP}$ $\frac{PE}{FE}$

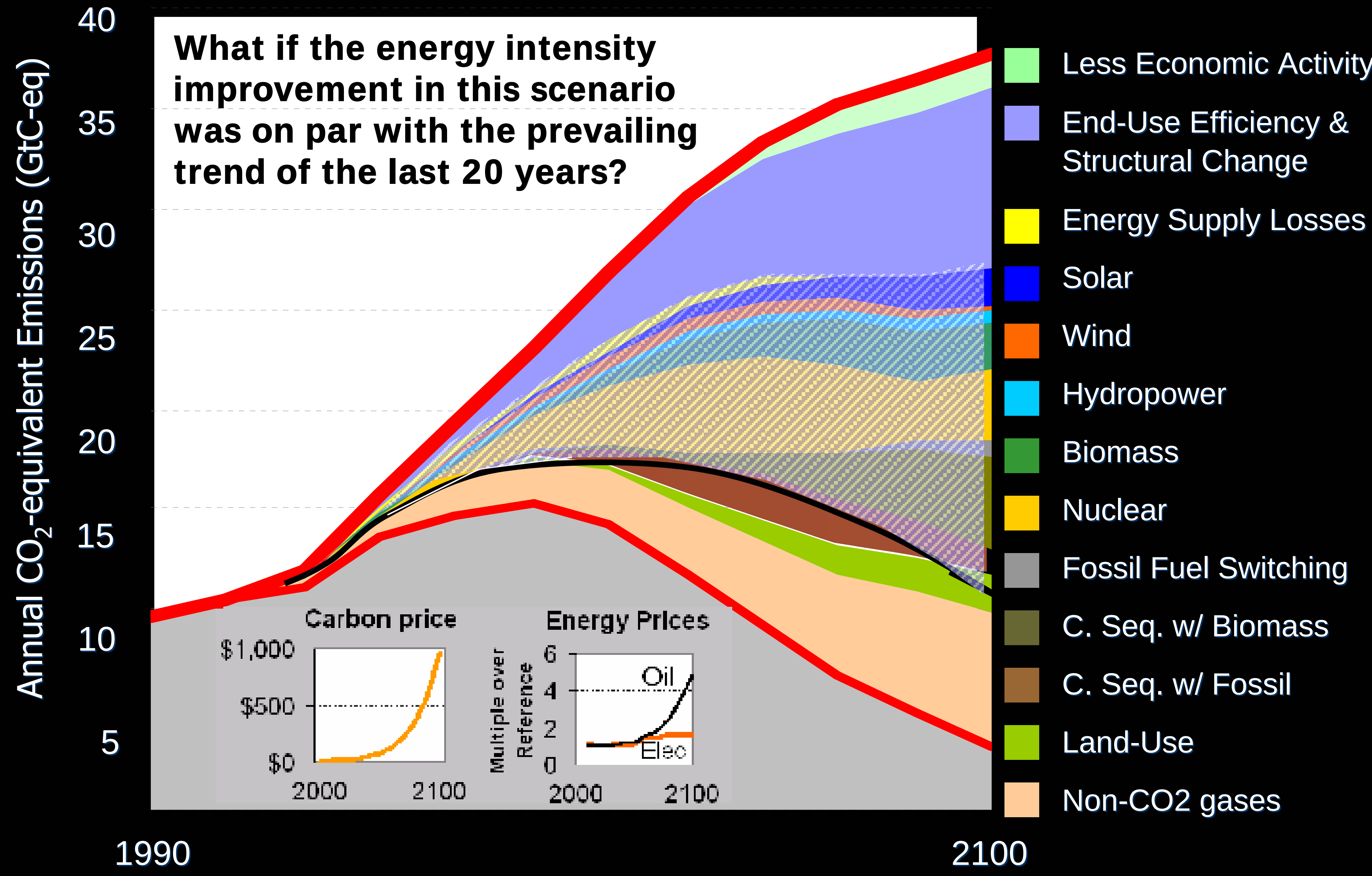
Carbon Shadow Price



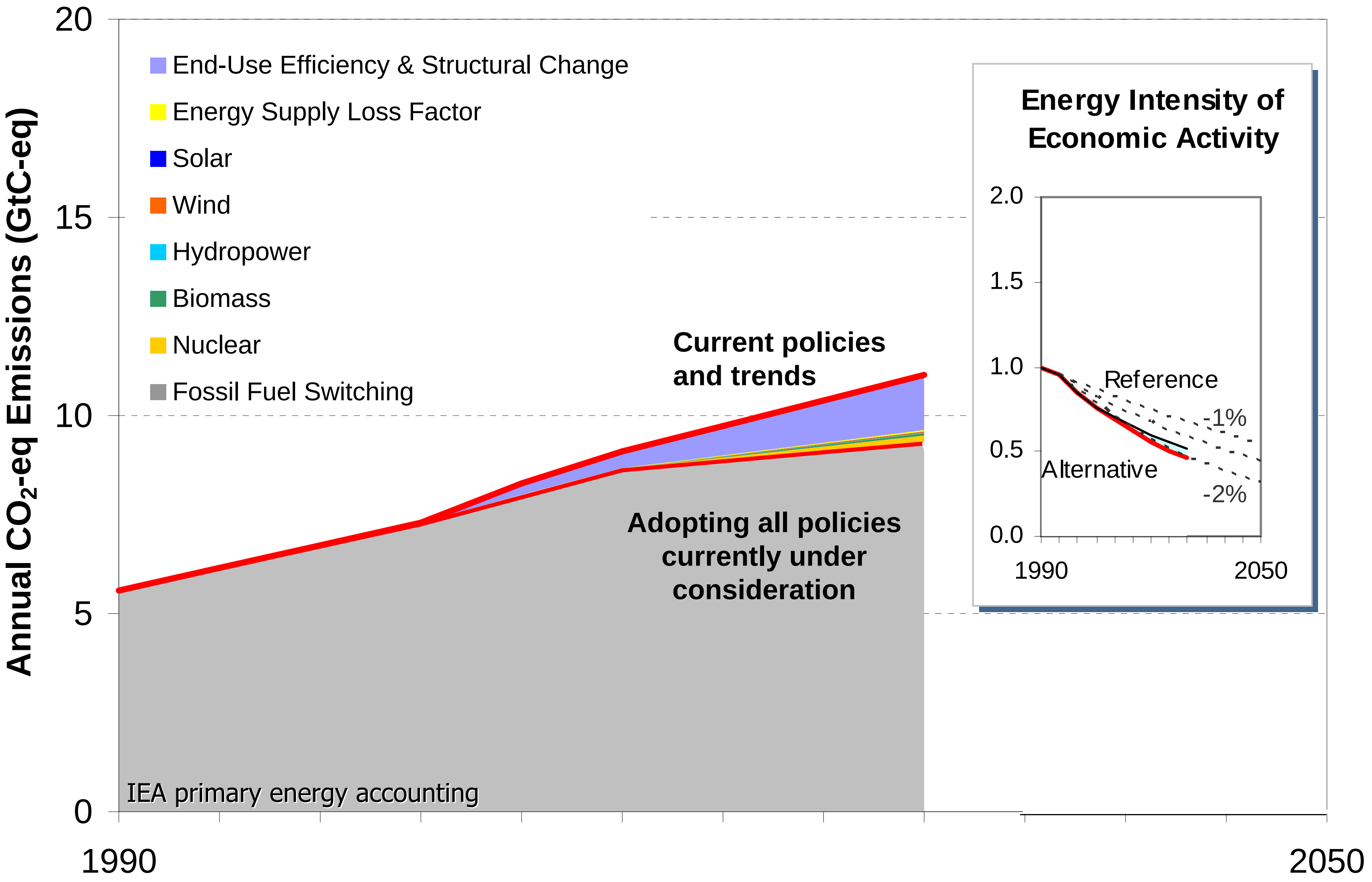
What if...?

Indexed to 1990=1

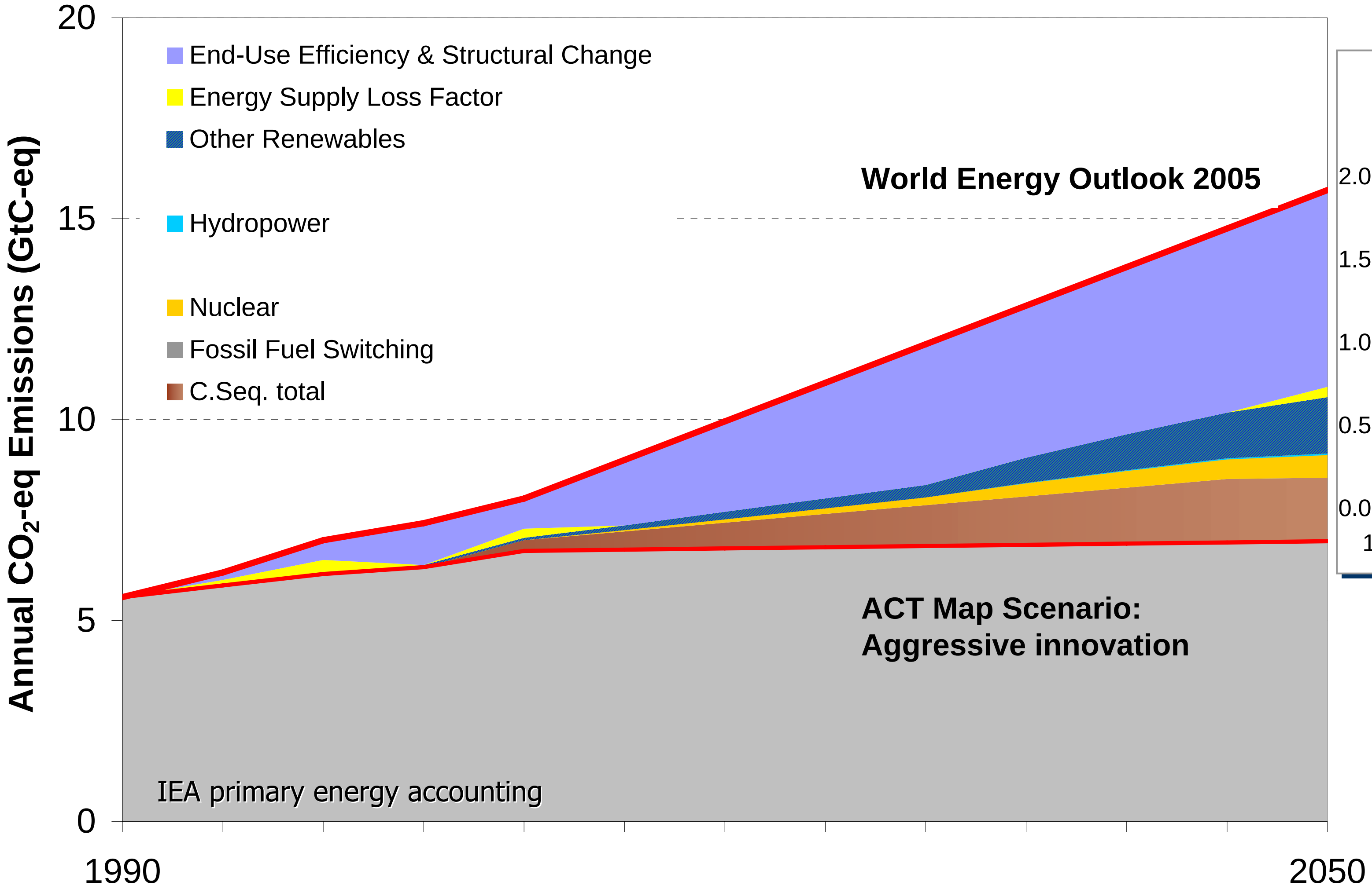
What difference does 0.5% make?

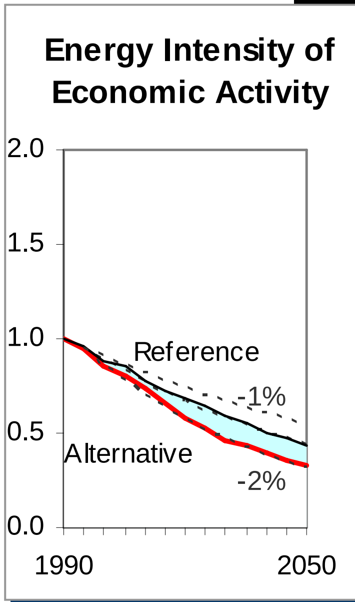


International Energy Agency, World Energy Outlook 2006

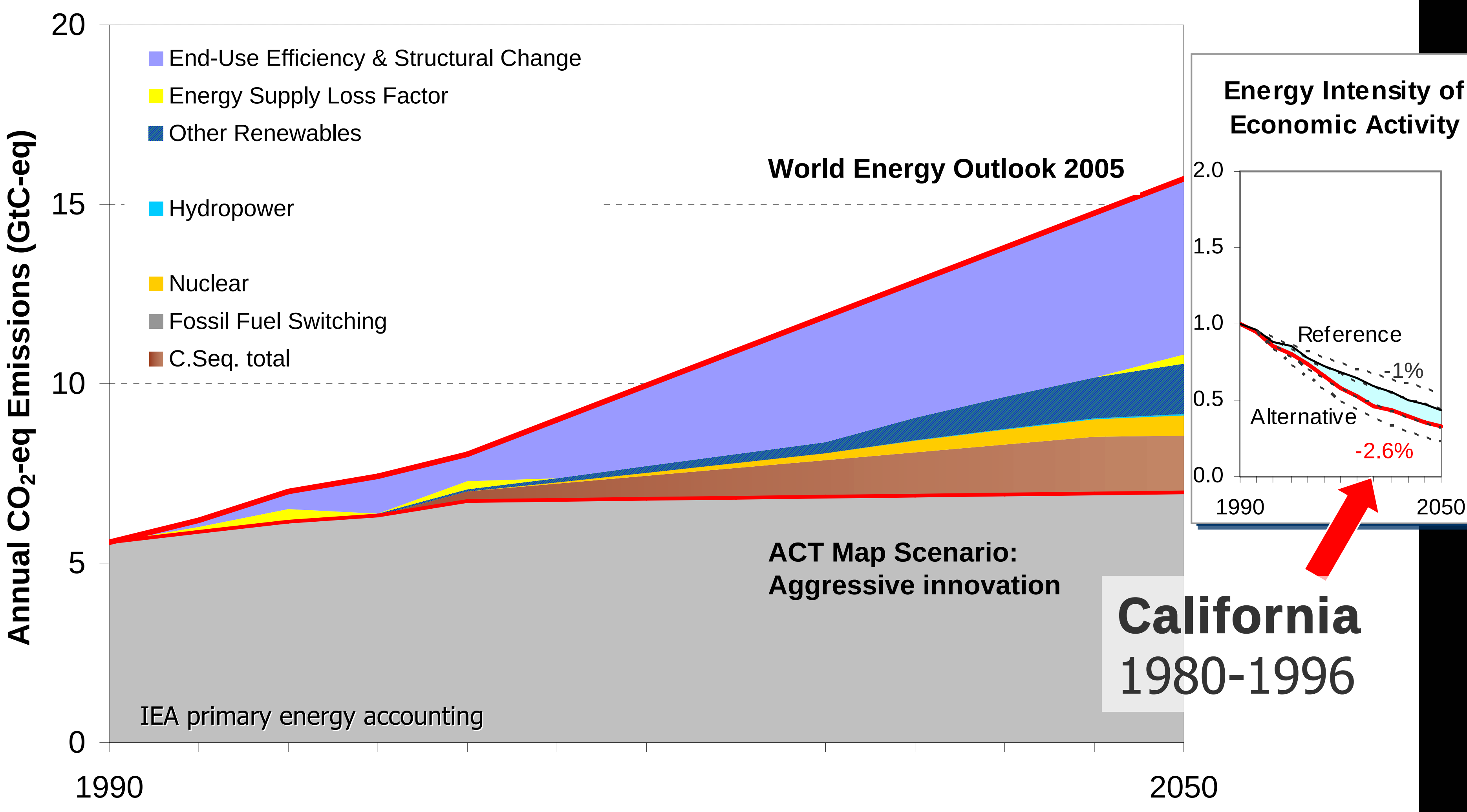


International Energy Agency, Energy Technology Perspectives

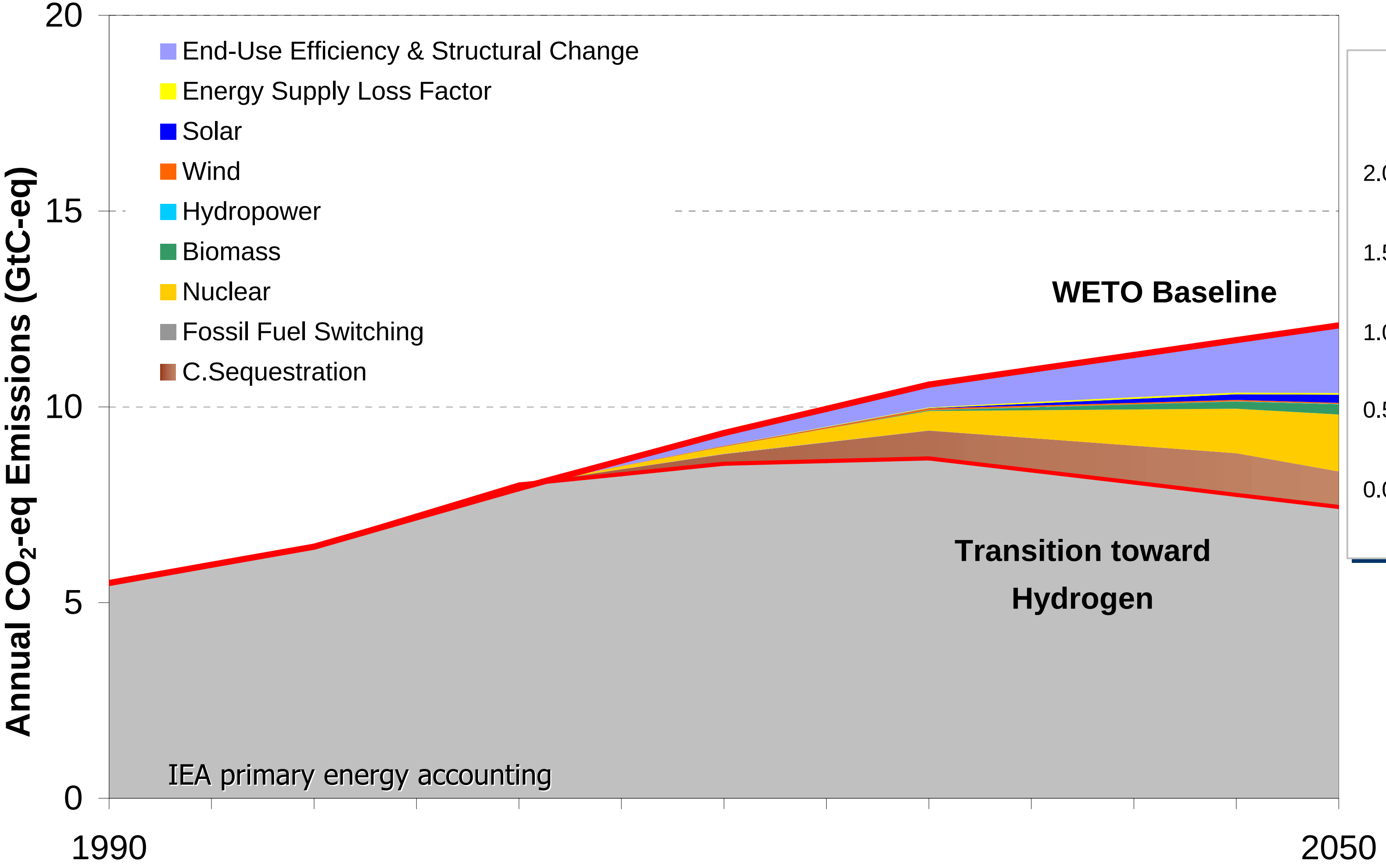


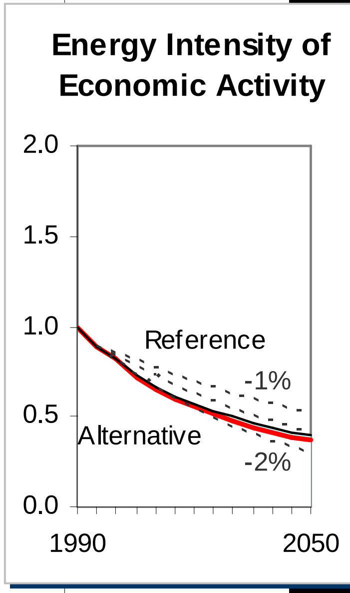


International Energy Agency, Energy Technology Perspectives

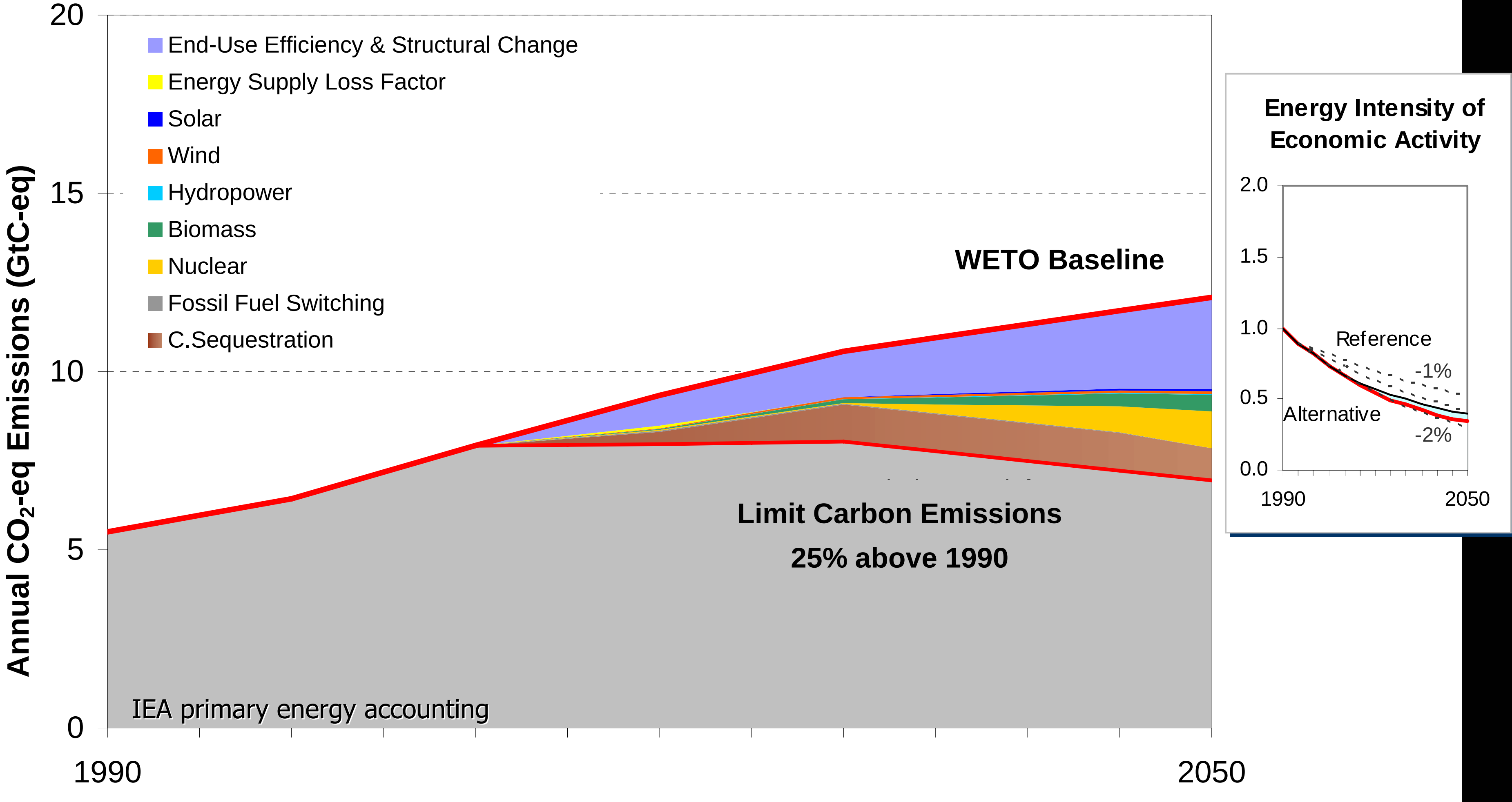


World Energy Technology Outlook 2050 (EU)





World Energy Technology Outlook 2050 (EU)



Exploring Energy Futures

model agnostic

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- What is the role of energy efficiency?
- Summary of findings, and your questions

Summary of Findings

- When sufficient data is disclosed, two decomposition techniques demonstrated can be applied to a wide range of energy scenarios to perform initial validation and assessment of diverse energy futures from a variety of sources, including bottom-up and top-down models.
- This type of analysis is necessary for discerning policy-relevant implications of scenarios generated with (infeasible) proxy policy interventions. (Burden sharing for a cap-and-trade proxy policy is needed to produce relevant regional results.)
- Data disclosure practices should be improved to provide at least the fields needed to identify sources of mitigation and impact on key drivers of emissions.
- The direct equivalent method deserves more attention, even reconsideration (esp. for nuclear power), and must not be ignored in any policy analysis that promotes fuel switching.
- This analysis is model agnostic, and it does not investigate the origins of demand reduction values from each model – whether using an AEEI function or a marginal cost curve for demand reduction. Data for either were difficult to gather.

Summary of Findings

- Application of these decomposition techniques indicate that the contribution of energy efficiency is often understated, straining energy supply options and leading scenarios to deploy high-risk technologies on a large scale.

- Environmental and social impacts of most large-scale supply-side mitigation have not been well investigated. ("We tend to like best the things about which we know the least.")

- Even when efficiency is taken into account, the level of effort implied by stabilization scenarios is staggering.

- Serious climate policy will include both price mechanisms and technology policy. Price mechanisms will only succeed with responsive energy markets and stable governance.

- We are all decision-makers in a "choose your own adventure" world.


INTERNATIONAL ENERGY AGENCY
WBGU
German Advisory Council on Global Change (WBGU)
solutions
Special Report on
s Scenarios
INTERGOVERNMENTAL PANEL ON CLIMA
WMO
Climate Change 2007: The Physical
Summary for Policymake
Contribution of Working Group I to the Fourth Assessment Report
Intergovernmental Panel on Climate Change
World Energy Outlook 2006
[r]evolution
A BLUEPRINT FOR SOLVING GLOBAL WARMING
EREC
EUROPEAN RENEWABLE ENERGY COUNCIL
PEW CENTER
Global CLIMATE CHANGE

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Stephen Schneider
Gil Masters
Jon Koomey

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Environmental Leadership Program
Interdisciplinary Program on Environment & Resources

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